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Knowledge management and institutional development within the British Nuclear Weapons Programme, 1947-1993

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Knowledge Management and Institutional Development within the British Nuclear Weapons Programme, 1947-1993

Submitted by

Geoffrey Chapman

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In the

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Table of Contents

Dedication

For Mum

To Laura, who knows more about AWRE than she ever expected

Abbreviations

ABM - Anti-Ballistic Missile

AEC - Atomic Energy Council

AEP – Atomic Energy Programme

AEX – Atomic Energy Executive

AGEX – Above Ground Experiments

ARD – Armament Research Department

ARE - Armament Research Establishment (ARD after 1948)

AWE – Atomic Weapons Establishment (1987-present)

AWRE – Atomic Weapons Research Establishment (1954-1987)

BNDSG - British Nuclear Deterrent Study Group

CA(P) - Chief Advisor (Projects)

CERN - Controller of R&D Establishments, Research and Nuclear

CSA – Chief Scientific Advisor

CSAR – Chief Superintendent Armament Research

CSSE - Chief Strategic Systems Executive

CTBT - Comprehensive Test Ban Treaty

DNP – Defence Nuclear Programme

DPRC – Defence Policy Research Council

HER – High Explosives Research (1947-1952)

JOWOG – US-UK Joint Working Group

MDA - Mutual Defence Agreement

MinTech – Ministry of Technology

MoD – Ministry of Defence

MoS – Ministry of Supply

NAST - Naval and Air Staff Target

NNSA - National Nuclear Security Administration

NRDC - Nuclear Requirements for Defence Committee

NWCSP - Nuclear Warhead Capability Sustainment Programme

ORC - Operational Requirements Committee

RAF – Royal Air Force

SofS – Secretary of State for Defence

SPA - Special Pay Additions

TNW – Tactical Nuclear Weapon

Abstract

Can nuclear weapons be uninvented? This thesis provides new insights into how this was a longstanding worry for the British nuclear weapons establishment and how it understood and responded to its knowledge management concerns. This thesis demonstrates how, from a sense of its own fragility, the British nuclear weapons establishment developed an understanding of the importance of personally embodied skills. Process tracing is used to highlight a cyclical pattern of the establishment believing itself to be in a morale crisis where it needed extra measures to retain tacit knowledge. In response, Aldermaston repeatedly promoted its institutional interests by raising the risk of nuclear weapons 'uninvention' through the loss of its skilled workforce unless more work could be obtained. Although not always successful, this argument was first deployed in 1954 and used as late as 1993. These efforts had a direct impact on nuclear policy; the Polaris Improvement Programme was initially justified based on maintaining the research momentum at Aldermaston. The inability to contest arguments premised on secret and incommunicable skills meant that successive governments were faced with the principal-agent problem of imposing enough oversight to ascertain Aldermaston's minimum manpower requirements yet also affording enough autonomy for the weapons establishment to manage its own workforce freely. To find an optimal balance, multiple different management models have been imposed upon Aldermaston. Nonetheless, this thesis demonstrates that claims relating to nuclear skill loss have and continue to serve as a driver for vertical nuclear weapons proliferation and may prove particularly influential in states less able to provide effective oversight.

Chapter 1: Research Question & Theoretical Framework

Introduction

How have nuclear weapons establishments responded to concerns over the loss of skill necessary for their function? This chapter will present the research problem and question of this thesis and establish why it is important for it to be examined. It will be argued that the difficulties in establishing and conveying the extent of a nuclear weapons establishment's knowledge management needs can serve as a driver for vertical proliferation. It will then be argued that Britain presents an ideal case study and an analysis of its historical experience from a knowledge management perspective can provide new insights. This chapter will then construct a theoretical framework through reviewing the relevant literature on knowledge management and nuclear weapons programmes, demonstrating the importance of sustaining skills and how this pressure complicates communication between policy makers and managers of the nuclear weapons establishment. The thesis will then proceed to apply these concepts to the history of the British nuclear weapons programme.

Problem Statement

MacKenzie and Spinardi demonstrated in 1995 that producing nuclear weapons was dependent upon an array of "tacit knowledge" based skills that required interpersonal transmission, if these were lost then nuclear weapons 'uninvention' could potentially occur.[1] This reflected the contemporary concerns of the US and UK weapons establishments at the end of the Cold War and underground nuclear testing moratoriums.[2] The possibility of nuclear weapons uninvention continued to be explored by numerous practitioners, academics and policy makers; the issue of 'uninvention' continues to be highly contentious given the possible policy implications for nuclear non-proliferation and stockpile maintenance.[3] A typical arrangement of the nuclear uninvention argument is that as nuclear weapons stored in arsenals need repair and maintenance to function

[1] MacKenzie and Spinardi, (1995), p.47
[2] Ibid., p.91
[3] Bourne, (2016)

properly, this introduces a classic 'Ship of Theseus' problem, wherein engineers and designers attempt to restore devices to as close to the original specification as possible to guarantee their reliability.[4] The problem with this approach, as recognised by the British nuclear weapons establishment by the 1970s was that "the copy will not be exact in a perfectionist sense. No specification can entirely exclude the need for skill and interpretation; people and facilities change."[5]

Research Question

The above problem raises the question – how have nuclear weapons institutions been affected by and responded to the problem of retaining skills to ensure their nuclear weapons continue to function? It also gives rise to a further problem – who other than those already within the weapons establishment are qualified to determine the level of skills needed? The overall objective of this thesis is to further understand how establishments have assessed and responded to concerns over nuclear weapons knowledge management. By studying the British historical experience, this thesis identifies a cyclical process of how Britain's nuclear weapons establishment experienced repeated morale and associated personnel crises. To avert the loss of the skilled workforce, administrators promoted the potential for nuclear weapons 'uninvention' to policy makers as identified by MacKenzie and Spinardi in 1995.[6] This argument, based on retaining tacit knowledge through continuing research and development, as well as improved conditions for personnel at the establishment was used to advance institutional interests repeatedly between 1947 and 1993.[7] This involved sequential steps of identifying knowledge management deficiencies internally, communicating them to policy makers, requesting action be taken and then policy implementation. This thesis highlights the repeating processes that led successive governments to face the dilemma over whether to provide autonomy to or centralise oversight over the weapons establishment and whether to provide further development programmes. Although potent, the 'uninvention' argument was rarely singularly successful. The case for further programmes premised on knowledge management grounds were most effective when governments lacked political consensus and delegated decision making to a limited nuclear bureaucracy.

[4] MacKenzie and Spinardi, (1995), p.92 - MacKenzie and Spinardi describe the 'Ship of Theseus' problem as one of retaining "the sameness of artifacts."
[5] TNA, DEFE19/240, UK Stockpile Reliability in the Absence of Nuclear Experiments, 01/02/1978
[6] MacKenzie and Spinardi, (1995)
[7] Ibid., p.44

Why Does It Matter?

This thesis primarily contributes to understanding nuclear weapons establishments' responses to knowledge management challenges, exploring how and why this can serve as a driver for vertical proliferation. In terms of domestic drivers of proliferation, Sagan notes that "state-run [nuclear] laboratories" play a role in "[serving their own] parochial bureaucratic or political interests," but recognises that "no well-developed… theory" exists in this regard.[8] Good case studies examining domestic drivers do exist for particular states. For example, Schilling and Young study the bureaucratic politics behind the US progression towards the hydrogen bomb and Kampani has investigated the role of institutions in India's nuclear decision making.[9] The role of the British weapons establishment in influencing nuclear decisions has also been highlighted before by Ritchie, Zuckerman, Spinardi and McLean & Beyer.[10] However, this thesis is distinct from these studies by examining these issues through the lens of knowledge management, applying this to the British nuclear weapons programme. Drawing on theories from the Science and Technology Studies field, this work constructs a conceptual framework for nuclear weapons knowledge management and demonstrates why it is an intrinsic aspect of development and maintenance. This framework is then applied to the British nuclear weapons programme, through the analysis of archival sources that were previously unavailable to the above studies. This thesis finds a consistent and repeated concern over retaining and transmitting skills that was established early on in Britain's nuclear weapons history that acted as a drive towards heterogenous engineering and the struggle governments had in attempting to acquire oversight over these efforts. This perspective provides an explanation of a drive towards promoting institutional interests by weapons laboratories that stems from apparent socio-technical necessity, rather than self-interest.

By demonstrating knowledge management challenges and how nuclear weapons institutions and policy makers have responded, this thesis has clear theoretical and policy implications. Academics such as Dennis, Carrigan and Kemp have recently argued that institutional knowledge requirements for nuclear proliferation are one of the only remaining barriers due to the diffusion of dual use relevant material and technology.[11] Correspondingly, Vogel, Hymans and Ouagrham-

[8] Sagan, (1996), p.63-65. See Palamar, (2016) for a recent thesis examining bureaucratic imperatives towards denuclearization.
[9] Young & Schilling, (2020) and Kampani, (2014)
[10] Ritchie, (2009), Zuckerman, (1989), Spinardi, (1997) and McLean & Beyer, (1987)
[11] Kemp, (2014), Carrigan (2007) & Dennis, (2013)

Gormley have advocated for non-proliferation policies focused on assessing intangible, social aspects of weapons programmes.[12] In terms of examining the influence and challenges of managing a nuclear weapons effort, Hymans and Braut-Hegghammer have examined several cases but their studies focus on authoritarian regimes conducting initial proliferation campaigns.[13]

While Hymans argues that severe knowledge management problems for nuclear weapons programmes occur most prominently in authoritarian regimes, this has been undermined by North Korea's recent advancements.[14] In response, Saunders has attempted to synthesise the existing scholarship on nuclear choices and domestic politics of nuclear states by comparing the degree of nuclear threat certainty against the expansion or contraction of nuclear policy making circles.[15] Within this framework, nuclear weapons scientists are necessary elite actors that can be delegated autonomy to "facilitate innovation" at the risk of exacerbating bureaucratic politics.[16] Alternatively, leaders may also "restrict the domestic circle for nuclear choices to exclude those who have different nuclear policy preferences."[17] Saunders cites India as an example of when leaders adopted the latter approach; Kampani concurs, making the case that India's nuclear decisions were driven by "[a] classic principal-agent problem. The principals, the political class in this case, lack[ed] the knowledge and expertise to effectively monitor their agents, both the scientific and military agencies."[18] Braut-Hegghammer also identifies that principal-agent problems limited Iraq's proliferation efforts as the state was unable to assess its scientists' work.[19]

In advancing this work, the problems encountered in Britain's nuclear programme highlight the inherent difficulties of managing a nuclear weapons programme as information asymmetries (relating to levels of 'skills' required to sustain the effort) mean the principal (UK government) was repeatedly forced to decide on its response to a perceived threat (possibility of nuclear weapons uninvention) near solely on information provided by the agent (the nuclear weapons establishment), with the agent being the only competent body able to authoritatively judge a proposed settlement.[20]

How Britain has responded to this central dilemma, by either delegating autonomy to or further centralising authority over the nuclear weapons establishment is an area of ongoing policy

[12] Hymans, (2012), p.269-273, Ouagrham-Gormley, (2014) and Vogel, (2013), p.275-276
[13] Braut-Hegghammer, (2016) and Hymans, (2012)
[14] Narang and Miller, (2018), p.71-72
[15] Saunders, (2019)
[16] Ibid., p.167
[17] Ibid., p.167
[18] Kampani, (2014), p.219
[19] Braut-Hegghammer, (2016), p.6-13
[20] Kampani, (2014), p.69 & p.73-75

concern.[21] Different approaches intended either to improve the ability of the weapons establishment to retain knowledge or increase oversight have persistently faced criticism. Multiple institutional developments made in attempts to resolve these perceived problems were significantly varied, providing the basis for this thesis' empirical research. As is highlighted in the theoretical framework, knowledge management for both an initial proliferation effort and then maintaining a nuclear arsenal has proven near universally challenging. Therefore, the UK case provides varied responses to the same consistent challenges. How states and institutions have responded to the possibility of nuclear uninvention and providing oversight over the nuclear weapons establishment will provide further policy tools to disarmament and non-proliferation efforts.

By producing a knowledge management framework and applying it to the history of a nuclear weapons programme, this thesis contributes to the literature that developed following the end of the Cold War and concerns over possible nuclear weapons 'uninvention'. As already cited, this most prominently consists of MacKenzie and Spinardi, but associated sociological studies include Nuclear Rites by Hugh Gusterson and McNamara's thesis on Los Alamos.[22] More recent studies include Sims and Henke's analysis of 'socio-technical repair' and Bourne's acknowledgement of the inherent politics of discussing the invention and uninvention of nuclear weapons.[23] While these studies have tended to focus on the ramifications of the end of nuclear weapons testing, this thesis highlights the continuities and dissimilarities between debates over nuclear weapons uninvention before and after the majority of states ratified the Comprehensive Nuclear-Test-Ban Treaty. Firstly, that the idea that nuclear weapons could be uninvented due to knowledge loss was not new and had been used to promote the institutional interests of Britain's nuclear weapons establishment as early as the 1950s. Secondly, this thesis underlines that the need to retain the ability to construct and maintain nuclear weapons reliability has long been understood as a social process that involved transmitting information between people through new research and development programmes. This is where a driver of vertical proliferation emanates from. However, it will be noted that this driver has been lessened in recent years due to a process of 'black boxing,' where reliance on previously individually embodied knowledge is transferred to an impersonal scientific process utilising computerised simulations.[24] While this is not an entirely new process, reliance on simulations has considerably increased and the conclusion to this thesis will demonstrate how this has occurred within the British nuclear weapons programme.[25] This may mean the significance of the driver

[21] See Plant, (2020)
[22] MacKenzie & Spinardi, (1995), Gusterson, (1998) and McNamara, (2001)
[23] Sims & Henke, (2012) and Bourne, (2016)
[24] MacKenzie & Spinardi, (1995), p.91-92
[25] The construction of a laser simulation facility is highlighted in chapter 6.

identified by this thesis is diminishing over time, but likely only in established nuclear programmes who have confidence in their data acquired in nuclear testing and ability to simulate nuclear weapons conditions.

While leveraging the existing literature on the UK's nuclear weapons programme as source material, this thesis will also make a significant contribution to the history of the British weapons establishment. Other than a brief history offered by AWE, no other work provides an in-depth examination of how the weapons establishment undertook institutional development from its foundation to the present.[26] As will be seen, these adaptations were often in response to perceived needs of acquiring and retaining skills. When expressed by contemporaries, their language may not directly match the terms detailed in the framework, but it is argued that the concepts involved do due to their ongoing need for interpersonal transmission and fear of permanent loss. By utilising new archival material and official histories that have been released in the past 20 years, each chapter will provide fresh insights into how knowledge management was handled, and how these concerns were communicated in each case study era selected by this thesis.

Why Britain?

Britain provides arguably the best-case study as to how variations in autonomy and centralisation were provided to the nuclear weapons establishment in attempts to resolve knowledge management issues.[27] This stems not only from the availability of primary source material, but the observable cyclical nature of how institutional development was undertaken in an effort to ameliorate knowledge management concerns or attempts to balance institutional autonomy, oversight and control over its nuclear weapons programme. When nuclear weapons development within the UK resumed after WW2, it initially came under the auspices of the Ministry of Supply. In 1950, development was centralised at Aldermaston as the Atomic Weapons Research Establishment (AWRE) and under the supervision of the United Kingdom Atomic Energy Authority (UKAEA) after 1954. During the 1960s, the UKAEA was subordinated under the Ministry of Technology. This was changed again in 1973 when the AWRE was subordinated directly to the Ministry of Defence (MoD). Finally, during the Thatcher government, AWRE was reformed into the Atomic Weapons Establishment (AWE) and transferred to privatised management between 1987

[26] See Hawkings, (2000). More broad ranging official histories exist, but they do not highlight the commonality of problems encountered across time.
[27] Hymans, (2012), p.25-29

and 1993. The management of the UK's nuclear establishment has therefore transitioned from a fully government directed initiative to a privately managed one and as a result, the UK provides a series of case studies that highlight alternating outcomes within a repeating process of attempts to autonomies or centralise the nuclear weapons establishment.

There are also still open questions with regards to Britain's nuclear weapons development and the influence of its weapons laboratory on its technical direction. For example, a puzzling outcome identified in the literature has been the variable ability of Britain's weapons laboratory to influence the technical direction of Britain's nuclear weapons programme. Zuckerman (Government Chief Scientific Adviser 1964-1971) believed that the weapons establishment's drive for technical improvements led the nuclear arms race, whereas Spinardi thought this may have only been the case for the Polaris Improvement Programme.[28] If Spinardi is correct, why was institutional pressure in this case successful but not in others? Spinardi identified the role of heterogeneous engineering and its relationship to the relative influence of the weapons establishment, but he was not able to fully explore the reasons for this variation due to source limitations.[29] This thesis identifies a cyclical process wherein the weapons establishment believed its inability to retain vital skills posed an existential risk to the programme unless new work was provided. It is argued that when governments delegate questions of nuclear 'uninvention' to their defence bureaucracies, retention of skill-based arguments will be most influential. Each case study chapter will demonstrate how this process unfolded, how it was attempted to be handled internally, how these concerns were communicated to policy advisors and what solutions were offered (if any) and how these were implemented.

The UK rests as perhaps one of the best documented weapons programmes compared to its contemporary proliferants like France or the Soviet Union, even before taking language barriers into consideration. Selecting the United Kingdom means access to a range of primary sources at the National Archives. The United States offers comparable levels of access but is different as it was the first to develop fission and fusion capabilities, thus presenting a different type of case as other countries were attempting to replicate technologies that had already proven to be physically feasible.[30] Collections of interest include those from the weapons establishment itself, the Ministry of Defence (MoD) and the UK Atomic Energy Authority, whereas comparable collections would still be highly restricted for the Soviet Union and France. However, there are some restrictions to access; for example, some senior figures' contemporary correspondence (such as William Penney's) are

[28] Spinardi, (1997), p.551-552
[29] Ibid., p.572-575
[30] Dennis, (2013)

retained without public access by the MoD.[31] In addition, this thesis was affected by an ongoing review of files held at the National Archives that was initiated in mid-2018. Files relating to the weapons establishment and Atomic Energy Authority were unexpectedly withdrawn and are still unavailable for access as of 2020.[32] While this has diminished the quantity of source material available for the latter chapters (with research material for earlier chapters having been mostly collected prior to the initiation of the review), enough material was available in the British case to make a detailed examination still viable.[33] For more recent developments, information from the Defence Select Committee and compiled by the Nuclear Information Service is used.

There also exist numerous well researched secondary works that consider the technical development of the UK's nuclear programme and can be used as sources. These include but are not limited to Matthew Jones' official histories, Kristan Stoddart's Palgrave series, Britain and the H-Bomb by Arnold and Pyne, Independence and Deterrence by Gowing, The Independent Nuclear State by Simpson and Test of Greatness by Cathcart.[34] Various articles were of assistance, including those by Baylis, Aylen's recent *First Waltz* and Moore's *British Nuclear Warhead Design 1958–66*. In short, there is no shortage of secondary source material on Britain's proliferation project except for the establishment's more recent history.[35]

A valid approach to researching British nuclear weapons history not undertaken by this thesis was the use of interviews. Previous ethnographic studies examining practices at US nuclear weapons establishments have made extensive use of interviews as the basis for their conclusions.[36] Interviews can also enrich a bureaucratic narrative: Cathcart's partially oral history of the early British nuclear weapons programme shows the merits of this approach.[37] However, the use of interviews for this study was limited by several factors. Firstly, many of the key agents in this study's narrative have passed away (e.g. Penney, Cook, Macklen and Quinlan). Persons of interest for this study (particularly for later periods) often remain in official positions or know sensitive technical information. Enlisting their support would raise a series of ethical and practical limitations (e.g. time constraints and access) given the subject matter still is under considerable classification restrictions. Those willing to speak publicly about their interactions with the British nuclear weapons establishment have tended to be sceptical of the enterprise (such as Zuckerman and David Owen)

[31] TNA, ES1/973, 1956
[32] Holzman, (2019)
[33] Each case study chapter discusses source limitations. Information was drawn from alternative file series.
[34] Jones, (1)(2017), Jones, (2)(2017), Stoddart, (2012), Stoddart, (1)(2014) Stoddart, (2)(2014), Arnold & Pyne, (2001), Gowing, (1)(1974), Gowing, (2)(1974) and Cathcart, (1994)
[35] Baylis, (1995), Aylen, (2015) and Moore, (2004)
[36] McNamara, (2001)
[37] Cathcart, (1994)

and have already supplied their views for academic analysis.[38] In contrast, the available archival documents of policy debates and propositions provide an accessible (if incomplete) contemporary, less retrospective record which contain a variety of positions that must be analysed critically.

Nonetheless, the early periods of this study would have been most enriched by interviews; the weapons establishment's staffs' experiences in the 1940s and 1950s informed the belief of a pressing need to retain skills. Evidence for this in Chapters 3 and 4 is drawn from papers included as miscellaneous annexes to files, which discuss individual scientists, engineers and technicians.[39] Although the passage of time made interviews of this cohort impracticable. When the ES and AB files (which pertain to the weapons establishment) become accessible after the ongoing security review, there remains scope for further research on the origins in the belief of contemporary senses of tacit knowledge.[40]

Framework

Introduction: What is Knowledge management?

With the research question established, the following section will present the framework from which Britain's nuclear weapons history shall be analysed with. This section will present a range of knowledge management concepts that have been claimed to be relevant to a particular branch of science and engineering: nuclear weapons development. Knowledge management emerged as a field of study in the 1990s, focused on the study of how organisations retain, utilise and transmit information necessary for their function.[41] Due to the application of knowledge management theory in thousands of studies across multiple disciplines (sociology, economics, business studies, philosophy etc.), there is no singularly accepted definition.[42] However, there are epistemological concepts that are routinely cited as being core concepts within the field.[43] The following section will review the applicable concepts and their literature in regard to nuclear weapons development, including the Science and Technology Studies concept of heterogeneous engineering and how these can be utilised to support a nuclear weapons establishment's institutional interests. The result will

[38] See Zuckerman, (1989) and McLean and Beyer, (1987), p.146
[39] E.g. TNA, AB16/1778, Donald Perrott to D.R. Willson, 09/07/1954
[40] Holzman, (2019)
[41] Schmidt, (2012), p.201-209
[42] Ibid., p.164
[43] Ibid., p.172

be the construction of a theoretical framework which will then be employed by this thesis in its examination of the British nuclear weapons effort.

Knowledge Management Concepts and Nuclear Weapons

Explicit Knowledge

In terms of the epistemology that will be examined in this thesis, the first component that needs to be understood is explicit knowledge. Derived from the philosophy of Michael Polanyi, explicit knowledge was succinctly defined by MacKenzie and Spinardi as "information or instructions that can be formulated in words or symbols and, therefore, can be stored, copied, and transferred by impersonal means, such as in written documents or computer files."[44] According to Collins, the general perception is that "explicit [knowledge] is taken as the norm" as it comprises all written information.[45]

Within the context of developing and maintaining nuclear weapons, the necessity of explicit knowledge is clear. Explicit knowledge includes all technical drawings, scientific data, computer codes, diagrams, imagery and non-personified training and educational resources that would inevitably be both used and created within a nuclear weapons program. The value of such information has long since been recognised – within a year of nuclear bombings on Japan, the US Atomic Energy Act of 1946 introduced the new concept of 'restricted data' which meant that sharing "all… [information]… concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power" was strictly prohibited unless it had already been expressly declassified.[46] Unsurprisingly, the Soviet Union also demonstrated a keen interest in nuclear weapons relevant explicit knowledge as they maintained an extensive espionage network centred on the Manhattan project. Information sent back to the Soviet Union included a diagram of an implosion type device (by David Greenglass), details of the URCHIN neutron initiator system (by George Koval) and large quantities of technical data developed at great expense (by Klaus Fuchs, amongst others).[47]

[44] Polanyi, (1966), p.4 & MacKenzie and Spinardi, (1995), p.45
[45] Collins, (2010), p.80
[46] US Government, (1946)
[47] Pagano (2014) & Schwartz (1996)

Given that any explicit information will be interpreted within a local context, the relative value of this data remains highly contested. Within the Soviet programme, one of the chief scientists, Igor Kurchatov, claims that information obtained via espionage was only used for checking indigenously produced results against the Americans', whereas Nikolai Alexandroff (in an effort to heap praise on the atomic spies according to Sagdeev) claimed that "there was no "Russian" atomic bomb - there only was an American one, masterfully discovered by Soviet spies."[48] In perhaps a more balanced assessment, senior Soviet Scientist, Abram Ioffe stated that the "information reduce[d] the volume of work by many months, facilitate[d] the choice of direction, and free[d] the Soviets from extended searches."[49] Holloway concurs, arguing that the stolen information allowed the completion of the Soviet nuclear programme in 1949 whereas it would otherwise have continued until 1951.[50] This undermines the point that MacKenzie and Spinardi make about how "the possession of explicit information generated by previous efforts has not eased… [nuclear weapons development] dramatically" as it apparently did in this case.[51]

Nevertheless, it has been argued that ever since the first series of nuclear proliferation attempts, the relevance of explicit knowledge as a barrier to nuclear weapons activity has diminished. As MacKenzie and Spinardi state, "much of the relevant explicit knowledge is now irrevocably in the public domain."[52] Even as early as 1958, the authors of the Nth Country Problem and Arms Control provided details on the physics behind nuclear explosives, leading them to state that "the legend of the [nuclear] 'secret' is totally obsolete."[53] Within a pre-existing nuclear programme, the retention of explicit knowledge is trivial as MacKenzie and Spinardi acknowledge that "barring social catastrophe, explicit knowledge, if widely diffused and stored, cannot be lost."[54]

However, the assertion that explicit knowledge plays no role in impeding nuclear weapons development ignores several relevant factors that could limit a nuclear programme.[55] For one, while many of the principles behind nuclear explosives have become publicly available, certain specific aspects remain challenging to research without access to classified materials or the ability to interpret and reconfigure other dual use items. This is apparently recognised to some extent by MacKenzie and Spinardi who stated that "the design of a fission bomb is fully public knowledge,"

[48] Schwartz (1996), p.106
[49] Ibid., p.106
[50] Holloway, (1994), p.366
[51] MacKenzie and Spinardi, (1995), p.76
[52] Ibid., p.47
[53] Davidon et al., (1958), p37
[54] MacKenzie and Spinardi, (1995), p.46
[55] Ibid., p.46

although only "at this general level."[56] The areas from which an understanding derived from the publicly available information would prove insufficient to operationalise certain technologies would likely include the specifics of nuclear hydrodynamics (including computer codes), advanced uranium enrichment technologies, different types of initiators, tamper designs, the exact requirements for explosive charge shaping and phasing for thermonuclear devices. It is interesting to note that these coincide with what remains 'restricted data' under classification provided by the US Department of Energy, indicating their enduring value to proliferation attempts.[57]

Collins introduces the concept of "concealed knowledge" and "logistically demanding knowledge," both of which have clear relevance to nuclear weapons information.[58] "Concealed knowledge" clearly refers to information that is purposefully withheld from public access by those in the know, while "logistically demanding knowledge" is information that is possible to express explicitly but is often not.[59] Both of these concepts work in unison – the 'concealed knowledge' of official classification keeps explicit knowledge on the specifics of nuclear weapons design out of the public domain; while it is possible to reconstruct some of this information from open sources, it would likely prove time consuming, as well as increase uncertainty in the final product. As recompiling this information would likely require a tacit understanding of the topic at hand, Revill and Jefferson refer to this use of explicit knowledge as "weak tacit knowledge."[60]

Reconstructed explicit knowledge from disparate sources would have to go through a process not too dissimilar to that of 'reinvention' as described by MacKenzie and Spinardi, as it would first have to be verified.[61] This can be observed in how some proliferation attempts start with extensive literature reviews to acquire enough explicit knowledge before they can act. For example, Frost quotes Stumpf, who states that "South Africa['s proliferation programme] began [with] a 'very modest investigation, confined to literature studies' into the peaceful use of nuclear explosives."[62] This also proves true for non-state actors – Aum Shinrikyo conducted a series of open source literature reviews before embarking on their unconventional projects.[63] The observation that secrecy can continue to impede proliferation in this way has been recognised by the policy

[56] Ibid., p.52
[57] See DOE/SO-70 series, for example: US Department of Energy, (2003)
[58] Collins, (2010), p.91
[59] Ibid., p.91-95
[60] Revill and Jefferson, (2013), p.3
[61] MacKenzie and Spinardi, (1995), p.47
[62] Frost, (2006), p.36
[63] Tu, (2016)

community: the US Office of Technological Assessment states that “secrecy [can be used] to restrict the flow of knowledge” thereby creating additional “obstacles” to proliferation.[64]

Not only must explicit knowledge be reassembled before it can be used, but it must also come from a trusted source to be believed: an inability to operationalise even basic explicit information led Al-Qaeda to search for the fabled nuclear material ‘red mercury’.[65] While multiple sources have indicated the fictitious nature of the substance, the alluring prospect to a conspiratorial mind-set of a method of avoiding many of the technical challenges associated with proliferation must have been too appealing. Without corroborating information or a tacit understanding of the subject at hand, if a recipient of explicit information cannot trust the veracity of the information they are provided, then it would be of limited utility. For externally acquired information to be used, it would either have to be checked against other trusted sources or be verified by experimentation – both may prove challenging depending upon the relevant information in question. In an apparent effort to exploit this factor, Risen claims that the United States provided Iran with flawed design schematics for a component used to detonate implosion type devices as part of Operation Merlin.[66] Ideally, the device would prove non-functional and diminish the Iranian nuclear establishment’s trust in externally acquired information. This move apparently failed according to Risen, as the Iranians had “created a strong base of sophisticated scientists knowledgeable enough to spot flaws in nuclear blueprints” in conjunction with information from the AQ Khan network and therefore unintentionally assisted their efforts.[67]

These constraints on operationalising explicit information help explain both the continuing justification for classification and the demand for nuclear information by potential proliferants and fledgling nuclear programmes. Even after there were supposedly no secrets to nuclear weapons, AQ Khan was providing large amounts of information, along with physical samples and equipment to assist proliferation among states – if the information was so readily available, then it would be expected that there would be no demand. Alternatively, it could now be argued that the AQ Khan network has raised the level of explicit knowledge about nuclear weapons available to states to such an extent that it could be dismissed as a trivial obstacle. Kroenig claims that "China assisted Pakistan with its nuclear program in the early 1980s with a package that included uranium enrichment technology, weapons-grade uranium, and a nuclear weapons design."[68] In turn, AQ Khan is believed

[64] OTA, (1993), p.19
[65] Daly et al, (2005), p.viii
[66] Risen, (2006)
[67] Ibid.,
[68] Kroenig, (2010), p.1

to have passed on this design on to several other countries.[69] It therefore appears that state nuclear aspirants are able to acquire sufficient explicit knowledge from external sources. However, even if it is accepted that a sufficient level of information exists to make basic nuclear weapons design relatively simple, this does not remove explicit information as a barrier, either historically or in the present: as Stewart argues, many of the associated technologies linked with proliferation, such as producing carbon fibre, demand a process of indigenisation which have associated explicit knowledge requirements. All this information would have to be acquired, reassembled and trusted before it can be acted upon.[70] However, this interpretative process requires a deeper understanding of the technologies involved; it is this sense that is developed in a more painstaking fashion and can be subject to loss, unlike explicit knowledge.

Tacit Knowledge

What is Tacit Knowledge?

How does one know how to ride a bike? Polanyi's 1958 'Personal Knowledge' argued that in addition to there being explicit information, there was also 'tacit' knowledge which enabled individuals to undertake a range of practices.[71] A basic definition of tacit knowledge offered by Polanyi was that it consisted of "a wide range of not consciously known rules of skill and connoisseurship which comprise important technical processes that can rarely be completely specified, and even then only as a result of extensive scientific research."[72] While MacKenzie and Spinardi's seminal 1995 article was the first to apply the concept of tacit knowledge to nuclear weapons, the literature on tacit knowledge and its application to nuclear weapons design has since developed.[73]

While the field of knowledge management has offered many definitions for the term 'tacit knowledge' over time, Collins has had notable success in utilising the concept for explaining the difficulties in replicating scientific experiments with his paper on TEA lasers and measuring the Q of

[69] Sanger et al., (2004), However, an IISS report notes that AQ Khan's design "did not include the associated electronics, cabling and firing sets. Also missing were some of the key scale drawings of the explosive lenses. The bomb design was about 95% complete and was far more detailed than what has been available on the internet or through other unclassified sources". See: IISS, (2007), p.79
[70] Stewart, (2015), p.42
[71] Polanyi, (1958), p.99
[72] Ibid., p.65
[73] MacKenzie and Spinardi, (1995), p.48

sapphire.[74] In both of Collins' studies, scientific results were only reproduced when people were transferred from institution to institution, receiving hands on training in person.[75] This approach has since been replicated by Vogel, with studies looking at biological weapons proliferation, particularly in the Soviet Union.[76] The laboratory at Stepnogorsk only became successful in producing anthrax after it received additional technical assistance from the Ministry of Defence in 1984.[77] The idea that successful transmission of nuclear weapons technology could only occur through interpersonal contact was recognised by Winston Churchill in 1945, who observed that the transmission of "practical production methods… would not be an affair of scientists or diplomats sending over formulas… any such disclosure would have to take the form of a considerable number of Soviet specialists, engineers and scientists visiting the United States' arsenals."[78] With tacit knowledge recognised as important to the production of nuclear weapons, the following section will examine the various sub-components of tacit knowledge as offered by Collins and illustrate how they could potentially affect the process of nuclear proliferation and the maintenance of a nuclear arsenal.

Spectrum between Weak Tacit and Explicit Knowledge

As previously highlighted by 'concealed knowledge' and 'logistically demanding knowledge', the disaggregation between explicit knowledge and what could be considered tacit knowledge is not absolute. As Polanyi later argued, seeing explicit knowledge and tacit knowledge as mutually exclusive and diametrically opposed is misleading - all explicit knowledge requires some tacit interpretation.[79] Rather than in an effort to deliberately hide information, knowledge transfer through impersonal means can prove an imperfect process due to the original author's fallibility in capturing the totality of the required information for its replication. Collins therefore introduces the concept of "relational tacit knowledge" and describes several mechanisms highlighting the limitations of utilising and transmitting explicit knowledge. [80] While Collins argues that 'relational tacit knowledge' could be conveyed explicitly, it should be perceived as tacit knowledge as it requires "matter-of-course imitation" for its transmission and replication.[81] Collins also argues that

[74] Collins, (1974) & Collins, (2001)
[75] Ibid.,
[76] Vogel, (2013)
[77] Ibid., p.114
[78] Kaiser, (2005), p.35
[79] Polanyi, (1967), p.314
[80] Collins, (2010), p.95-6
[81] Ibid., p.96

'logistically demanding knowledge' and 'concealed knowledge' should therefore also be considered tacit knowledge as little understanding of the subject at hand would likely prove a barrier (if not insurmountable) for the information's reassembly.

The three forms of 'relational tacit knowledge' presented by Collins which are best described as a 'weak' form of tacit knowledge' are "mismatched saliences", "unrecognised knowledge" and "ostensive knowledge."[82] 'Ostensive knowledge' is information that is better conveyed when instruction is combined with proximity to and physical manipulation of equipment. What separates 'ostensive knowledge' and somatic tacit knowledge according to Collins is that the information conveyed could potentially be recorded explicitly.[83] Perhaps the most common of these are instances of "mismatched saliences" which occur when the author of a piece of work intends to convey the instructions for a process but assumes a too high level of institutionalised practices and background information for it to be interpreted correctly. As Collins indicates, it is practically impossible to remove this as a factor "because however hard the teller tries to tell all, he or she cannot do it."[84] 'Unrecognised knowledge' is when crucial practices carried out unwittingly by the author go unrecorded because their importance has not been realised.[85] As a result, necessary details are missing and therefore results cannot be replicated.

While from an external perspective it may seem unlikely that any nuclear weapons technology would be developed without a clear understanding of its functional characteristics, an outstanding example of the limitations of knowledge transfer impacting the production of nuclear weapons has already been highlighted by Last and Ouagrham-Gormley with the troubles that the US nuclear weapons establishment had with replicating FOGBANK.[86] FOGBANK is the codename for an aero-gel substance, critical in the inter-stage process for several types of US and UK thermonuclear weapons. New FOGBANK was needed as part of efforts to sustain life extension programmes for several types of warheads.[87] This substance was produced at the Oak Ridge Y-12 site in building 9404-11 from 1975 until 1989.[88] A lack of demand for new nuclear weapons in a post-Cold War world combined with the likely cost of refurbishing building 9404-11, which was due to be decommissioned in 1993, saw use of the site scaled back to only making small test batches of FOGBANK.[89] However, in 2000, the National Nuclear Security Administration (NNSA) undertook life

[82] Collins, (2010), p.90-97 & Revill and Jefferson, (2013), p.3
[83] Ibid., p.93-4
[84] Collins, (2010), p.95
[85] Ibid., p.95-6
[86] Last, (2009) & Ouagrham-Gormley, (2014), p.31-32
[87] Lewis, (2008)
[88] Last, (2009)
[89] Ibid.,

extension programmes for the W76, W80 and B61-7/11 warheads, prompting the approval of renewed large-scale FOGBANK production.[90] However, the original 9404-11 production facility had been largely abandoned since 1993, so it was decided in 2003 that the construction of a new production facility was necessary.[91]

While this new facility was produced at great expense (~$50 million) and started to produce minimal test batches in 2007, it was found that the new FOGBANK was relatively impotent.[92] This proved intensely problematic as "the precise techniques used to manufacture Fogbank were [by now] forgotten."[93] According to Lillard, efforts to replicate old manufacturing methods were foiled as "some of the historical design records were vague and that some of the new equipment was equivalent, but not identical, to the old equipment."[94] This created a critical situation for the NNSA due to the necessity of producing this material - they upgraded the project to "Code Blue", making it the agencies chief priority.[95] At a cost of a further $69 million and 19 months of work, a process equivalent to the historical method was resolved and able to produce working FOGBANK.[96] After further investigation, it was found that modern purification processes were removing too much of an essential chemical that was necessary for FOGBANK's good function – however, this was only discovered after the NNSA had reverted to a reconstructed form of the historical process.[97] This episode clearly highlights both the value of the 'unrecognised knowledge' of the necessity of the impurity and the effects of the 'mismatched saliences' in introducing vagaries into the recorded production processes, thereby exacerbating the effort required to reproduce them. This appears to be confirmation of a quote highlighted by MacKenzie and Spinardi from a 1987 report to congress which states that "[US] documentation [on nuclear weapon's manufacturing processes] has never been sufficiently exact to ensure replication...we have never known enough about every detail to specify everything that may be important."[98]

Somatic Tacit Knowledge

[90] Lillard, (2009), p.20, Last, (2009) & NNSA, (2003), p.8
[91] Last, (2009) & NNSA, (2003), p.12
[92] Last, (2009)
[93] Lillard, (2009), p.20
[94] Ibid., p.20
[95] Last, (2009)
[96] Ibid., p.
[97] Lillard, (2009), p.21
[98] MacKenzie and Spinardi, (1995), p.64-65, quoting Miller et al., (1987), p. 25

In contrast to 'weak' tacit knowledge, Collins argues that 'somatic tacit knowledge' is internalised and impossible to render explicitly.[99] While relational tacit knowledge's transmission is aided by social interaction and repeated close proximity with those who are already in the know, person to person interaction is the only method by which somatic tacit knowledge can be transferred. As already noted, the classic example provided by Polanyi demonstrating the need for tacit knowledge is of how to ride a bike. [100] This has since been reiterated by Collins, MacKenzie and Spinardi and Revill and Jefferson.[101] As somatic tacit knowledge is embodied in people, MacKenzie and Spinardi rightly point out the information's inherently local character, as it is tied to specific individuals.[102]

While the idea of ineffable, physically embodied skill may seem remote from nuclear weapon design, MacKenzie and Spinardi highlight the field of producing reliable nuclear primaries in particular as being dependant on tacit knowledge.[103] For the majority of America's nuclear history, nuclear engineers were able to verify the reliability of their designs through an iterative process of full nuclear testing. However, they argued adoption of the CTBT could potentially disrupt the process by which designers developed an intuitive understanding of how nuclear implosion devices worked.[104] Understanding how to build nuclear devices with enough energy retained to detonate secondary stages was understood as an intuitive skill, developed through testing experience.[105]

MacKenzie and Spinardi's interviews with US weapons engineers suggested that minor variations in materials and conditions meant that accommodating for all possible circumstances was impossible, thereby making a sense of whether a weapon will work reliably more of an "empirical art," than a hard science.[106] Therefore, the most important quality imparted by a tacit understanding of nuclear weapons relevant technologies is that of good "judgement."[107] It was through the ending of the accumulation and transmission of this 'skill' through the halting of nuclear testing and the design of new nuclear weapons that resulted from the end of the Cold War and CTBT that led MacKenzie and Spinardi to predict the potential for the "uninvention of nuclear weapons."[108] Without access to this sense of judgement, MacKenzie believed that only "relatively crude nuclear

[99] Collins, (2010), p.99
[100] Polanyi, (1958), p.51-52
[101] MacKenzie and Spinardi, (1995), p.45, Collins, (2010), p.99, Revill and Jefferson, (2013), p.3
[102] MacKenzie and Spinardi, (1995), p.46
[103] Ibid., p.59-60
[104] Ibid., p.60-61
[105] Spinardi, (1998), p.250
[106] Ibid., p.62
[107] MacKenzie and Spinardi, (1995), p.62
[108] Ibid., p.42

weapons" with limited military utility could be produced – boosted or thermonuclear weapons would be out of reach.[109]

Other areas of nuclear weapons work influenced by tacit knowledge highlighted by MacKenzie and Spinardi include the machining of nuclear weapons components (especially the creation of spherical fissile pits), visual quality assurance and the creation of reliable conventional explosive shaped charges.[110] According to Kroenig, the design of gaseous diffusion centrifuges, which is now the preferred method for the enrichment of fissile material, also requires a degree of tacit knowledge: "inexperienced engineers" are liable to overstrain their centrifuges, causing them to self-destruct.[111] Conversely, an abundance of relevant somatic tacit knowledge can enhance a programme – Lewis and Zimmerman note that Yuan Gonfu was able to shape China's first uranium pit overnight based on his years of experience with his equipment rather than specific instruction on fissile metal metallurgy.[112]

While the maintenance of existing knowledge was the problem that Collins and MacKenzie and Spinardi were primarily concerned with, both recognise that there is a difference between initial transmission and rediscovery of a lost art.[113] As Collins observed during his investigations into replicating TEA lasers, the most efficient means of transferring this knowledge is via interpersonal exchange.[114] In a clandestine (or at least isolated) nuclear programme, it is unlikely that states would ever be able to receive the totality of the somatic tacit knowledge that they required from hiring rogue foreign scientists due to the number of separate tasks involved.[115] Even in the case of foreign state assistance, Montgomery has argued that somatic tacit knowledge may not get transferred as assisting states tend to supply technology rather than train indigenous workers.[116] Simply having access to relevant technologies avoids the iterative developmental process which is needed for the acquisition of tacit knowledge and therefore may be counterproductive.[117] This is especially important within the context of nuclear proliferation as MacKenzie and Spinardi argue that it is a challenge that consists "predominantly [of] practical engineering problems rather than, for example,

[109] MacKenzie, (1999), p.192
[110] MacKenzie and Spinardi, (1995), p.63-4
[111] Kroenig, (2010), p.155
[112] Lewis and Zimmerman, (2009)
[113] MacKenzie and Spinardi, (1995), p.88 & Collins, (2010), p.99
[114] Collins, (1974), p.176
[115] Harney et al., (2006)
[116] Montgomery, (2013), p.179-180 & p193
[117] Ibid., p.179-180

deficits in explicit knowledge of nuclear physics."[118] Therefore, the ability to develop and retain nuclear tacit knowledge internally is of critical importance to nuclear weapons programmes.

Examples highlighting the limitations of exploiting externally acquired explicit information due to a lack of tacit knowledge may include the failure of the Libyan programme and the protracted development of North Korea's nuclear capability. In both cases, each state is believed to have received a significant amount of explicit information and physical samples from the AQ Khan network but were unable to successfully utilise them due to an inability to adapt them to local circumstances and constraints.[119] Montgomery cites a claim that the North Koreans may have initially "slavishly followed a recipe," without the pre-requisite technical ability to do so, and thereby hindered their own progress.[120] Similarly, Kemp strongly argues that this was initially the case with the Pakistani's efforts to develop a CONR centrifuge from information acquired from URENCO and also with Iran, when they provided incomplete information on the P1 centrifuge from AQ Khan.[121] If the need arose to deviate from externally acquired explicit instructions, which would almost certainly be the case in a nuclear weapons programme, a certain level of interpretation, improvisation and innovation would be required on behalf of the proliferators or those attempting to follow legacy instructions. While sociologists involved in knowledge management disagree as to the source and process of innovation, most describe it as having a tacit component: these range from the "crude empirical methods" that take place without "a deep scientific knowledge" described by Rosenberg or through the process of "internalisation" as described by Nonaka et al.[122] This applies to established nuclear weapons programmes too. As will be seen in the British nuclear programme, utilisation of American information did not make the process of making nuclear devices trivial; foreign designs had to be adapted to local conditions which required a deep understanding of the technology at hand.[123]

As a result, when exploiting nuclear weapons technology, it appears that it is first necessary to build a base of relevant tacit knowledge before meaningful progress can be made. Once gained, this tacit knowledge can be lost as it is embedded within people and practiced over time. 'Reinvention' of tacit knowledge as compared to transmission would likely be a painstaking process, but Collins recognises that "rediscovery of non-social kinds of tacit knowledge is always a

[118] MacKenzie and Spinardi, (1995), p.74
[119] Montgomery, (2005), p.177
[120] Ibid., p.177
[121] Kemp, (2014), p.65-66 & p.69-70
[122] Rosenberg, (1982), p.143, Leonard and Sensiper (1998) & Nonaka et al., (2000)
[123] Arnold and Pyne, (2001), p.214-215

possibility."[124] As already argued in the cases of proliferation for Iran, North Korea and Pakistan or with FOGBANK within the United States' established nuclear arsenal, tacit knowledge poses another obstacle to progress on nuclear weapons development. MacKenzie and Spinardi concur, stating that "the requirement for tacit knowledge thus serves as the equivalent of friction in a physical system: slowing things down."[125] This knowledge management problem is not an absolute barrier to the progress of a nuclear weapons project in the same way that access to some physical materials or the pre-requisite political will could be, but a lack of tacit knowledge could impose operationally significant delays and substantially increase costs. Koch has argued that delays (although she argues that they are the result of supply-side constraints) have already "change[d] leaders' strategic calculations regarding the value of their nuclear weapons programs" within select cases, sometimes leading to their abandonment.[126]

Black Boxing

Crediting the ideas forwarded by Latour, MacKenzie and Spinardi suggest that the continuing need for somatic tacit knowledge may diminish as many nuclear weapons relevant technologies could become progressively "black boxed."[127] 'Black boxing' (also referred to as 'deskilling') is a process by which the prerequisite skills necessary for the completion of a task, which were once embodied in individuals, become increasingly unnecessary through improved equipment. The example that MacKenzie and Spinardi provide include advances in computing and the greater availability of diagnostic equipment for implosion devices.[128]

This theme is highly evident in the resurgence of literature concerning biological weapons and tacit knowledge. The central question is whether advances in genetic engineering have trivialised the creation of bioweapons.[129] Recently, Kroenig and Volpe have expressed their concerns over whether additive manufacturing methods are making nuclear proliferation easier.[130] Others, such as Christopher are more tempered, stating while it is not currently the case, future technologies are likely to enable the easier production of proliferation sensitive materials such as maraging steel (which is used in advanced centrifuge designs).[131] Computer numerically controlled machinery,

[124] Collins, (2010), p.99
[125] MacKenzie and Spinardi, (1995), p.88
[126] Koch, (2019), p.773
[127] MacKenzie and Spinardi, (1995), p.78-81 & Latour (1987), p.1-17
[128] MacKenzie and Spinardi, (1995), p.78-79
[129] See: Revill and Jefferson, (2013), Jefferson et al., (2014) & Tucker, (2011)
[130] Kroenig and Volpe, (2015)
[131] Christopher, (2015), p.18 & 25

particularly precision lathes, have been suggested to have made the manufacturing of pits significantly easier, where otherwise it would have required a skilled craftsman.[132]

While 'black boxing' may aid nuclear proliferants, it has a complex relationship with maintaining existing arsenals. The key question for the role of 'black boxing' has been whether it has allowed for nuclear weapons to remain credible after the CTBT. With no nuclear testing, nuclear weapons certification in the US has become reliant upon computer simulations under the Stockpile Stewardship Programme, which rely on data from previous tests.[133] The inability to adapt and improve upon these codes in the absence of new explicit knowledge was a concern to MacKenzie and Spinardi who believed that weapons establishments may become "no longer developers of new weapons but custodians of past ones," a job that would get progressively harder due to an inability to retain "the sameness of artefacts" due to tacit knowledge loss (as seen with FOGBANK).[134] Latour noted that "paradoxically, the more science and technology succeed, the more opaque and obscure they become."[135] Therefore, while 'black boxing' may assist in the maintenance of nuclear arsenals in the near term, it is unlikely to fully eliminate tacit knowledge requirements when a deep understanding of the technologies involved is required.

Collective Knowledge

The logical progression from the idea that tacit knowledge is a locally acquired attribute and dependent upon interpersonal transmission is that a bank of tacit knowledge can be stored within a particular community in order to facilitate its function. In referring back to the bike analogy, Collins suggests that this type of knowledge is demonstrated in how individuals navigate traffic in a socially acceptable way.[136] In the context of a collective enterprise, this was the idea behind Lave and Wenger's concept of 'communities of practice' and first applied to nuclear weapons by McNamara.[137] Although McNamara was interested in how all the workers at US nuclear laboratories developed a shared sense of identity and values, Vogel's interpretation of her work is that it demonstrated a type of "communal synthesised tacit knowledge that cannot be separated out into individual components and is therefore more difficult to transfer."[138] This has obvious ramifications

[132] Pluta and Zimmerman, (2006), p.62-63
[133] Sims and Henke, (2012), p.335 & McNamara, (2001), p.236-237
[134] MacKenzie and Spinardi, (1995), p.91-92
[135] Latour, (1999), p.304
[136] Collins, (2010), p.119
[137] Lave and Wenger, (1991) & McNamara, (2001), p.26
[138] Vogel, (2013), p.118

for nuclear weapons development. For proliferation, even the transfer of individuals who hold relevant somatic tacit knowledge (such as rogue foreign scientists) would be insufficient to produce results as their work is tied to specific institutions. For existing nuclear arsenals, this would suggest that breaks in practice or the dispersal of a pre-existing organisation would inhibit the ability of the institution to be reconstituted later.

While MacKenzie and Spinardi mostly focused on the role of 'key' weapons designers, they hinted at the importance of tacit knowledge at a collective level with the suggestion of how US nuclear weapon designs "were the products, not of individuals, but of a complex, differentiated organization" and how there existed "communally sanctioned knowledge."[139] Nevertheless, Sims' main criticism of MacKenzie and Spinardi's idea was its over emphasis on individuals, instead arguing that there existed "transactional knowledge" that was shared amongst different parts of the weapons community.[140] 'Transactional knowledge' differs from collective/communal tacit knowledge in that it is less centralised and homogenised, instead being distributed among particular technical specialities which have to negotiate amongst each other for a coherent result.[141] This places an emphasis on the structure and management of a weapons programme given the large number of interlinked tasks that scientists and engineers have to complete in coordination with each other.[142] Sims also recognises that this fragmentation of tacit knowledge provides further evidence for its importance as "the core knowledge of each [technical] group has remained distinct and apparently inaccessible to experts in other fields."[143] The difficulty in transmitting this information even within a single establishment would imply that each element of a weapons programme would have to be developed and maintained through continuous practice for the programme to continue to be able to produce viable devices.

Management and Leadership

If it can be accepted that promoting effective knowledge management plays a role in facilitating nuclear proliferation and the maintenance of an arsenal, then how a programme is managed would also be expected to have an impact on its efficiency. This was the conclusion reached by Sims on 'transactional knowledge' when he stated that in assessing proliferation, one "should also look at whether the country in question possesses the cultural outlook and experience

[139] MacKenzie and Spinardi, (1995), p.58 & 63
[140] Sims, (2007), p.1
[141] Ibid., p.6
[142] Harney et al., (2006)
[143] Sims, (2007), p.1

with building interdisciplinary collaborations required to sustain a large-scale research and development program."[144] The organisation, development and dissemination of relevant tacit knowledge has consistently been argued to have been facilitated by effective leadership, according to the school of 'knowledge management' headed by proponents such as Nonaka and Takeuchi.[145] An appreciation of these factors' impact on proliferation has recently been incorporated into the works of authors such as Hymans, Ouagrham-Gormley and Braut-Hegghammer.[146] This allows for an added layer of analysis of the conditions that can negatively impact a nuclear programme, such as the impact of extreme ideologies and over interference. [147]

Hymans has produced the most developed work on the role of management on nuclear proliferation after having observed the declining efficiency of nuclear proliferation attempts over time not being well explained by commonly offered variables, such as the Nuclear Non-proliferation Treaty and the lack of political will. [148] In a position similar to that advocated by Sims and Nonaka, he contends that "it stands to reason that the effects of good or bad management on the efficiency" of proliferation will be noticeable given the "huge managerial challenge of nuclear weapons projects."[149] Although not framed within the perspective of tacit knowledge, Hymans analysis is arguably strengthened by it: if poor management impedes the spread of tacit knowledge, then it provides a direct causal mechanism that can explain why poor management fosters inefficiency.

Hymans argues that states and individual institutions can be split between neo-patrimonial and Weberian legal-rational management styles.[150] According to Hymans, a neo-patrimonial institution regularly interferes in the work of the personnel involved whereas a Weberian legal-rational one respects their "autonomy," thereby enabling them to "apply their *individual* [sic] knowledge" and "strongly promotes teamwork."[151] The main example he provides of neo-patrimonialism interfering with a nuclear weapon's project is how Iraq's efforts were scuppered by Hussein Kamel's "bureaucratic empire building, crudely authoritarian motivational strategies, and wanton foreign procurement binge."[152] According to both Hymans and Ouagrham-Gormley, one of the chief ways in which authoritarian leadership styles can negatively impact 'big science' projects is

[144] Ibid., p.10
[145] Nonaka and Takeuchi, (1995)
[146] Hymans, (2012), Ouagrham-Gormley, (2012) & Braut-Hegghammer, (2016)
[147] For example, see Danzig et al., (2012) on the role of these factors on Aum Shinrikyo's biological weapons efforts.
[148] Hymans, (2012), p.3-5
[149] Ibid., p.22-23
[150] Ibid., p.41-56
[151] Ibid., p.51
[152] Ibid., p.123

by imposing arbitrary deadlines for workers, with the possibility of sanctions if they are not met: this creates an organisational culture where workers simply follow directions, rather than focusing on innovation, collaboration and sharing knowledge.[153]

In contrast, Hymans suggests that Weberian legal-rational states and institutions can foster good leadership by offering "inspiration and facilitation" that develops "professionalism," which is defined as "institutionalized autonomy… discretionary specialization and a sense of vocation… [along with] a rigorous formal education system to the next generation."[154] Unfortunately, how this process occurs remains underdeveloped as Hymans does not provide a full case study on a Weberian legal-rational state. He does however examine China, where he argues that their nuclear programme was successful due to functional professional management on a 'micro' scale.[155]

This approach has received criticism as North Korea, the "poster boy for [neo-patrimonialism within] this theory," has achieved considerable recent success in advancing its nuclear weapons programme.[156] In terms of additional nuance that "[moves] beyond blunt distinctions between democracies and autocracies," Saunders' work suggests additional variables guiding domestic nuclear weapons policy.[157] These include the clarity of the perceived threat and the expansion or contraction of the circle of actors involved in nuclear decision making.[158] The interaction of these variables can result in degrees of centralisation or delegation in nuclear decision making across different states.[159] Saunders' model helps explain why scientists are sometimes granted influence over nuclear weapons policy, afforded autonomy or otherwise subjected to assertive control and monitoring.

Within Saunders' framework, Britain's nuclear weapons establishment experienced comparatively benign conditions. The contraction of actors involved in decision making never matched her 'centralizers' or 'gamblers' paradigms.[160] Instead, AWRE either faced a 'mobilised' bureaucracy providing oversight over the nuclear programme or enjoyed the 'delegated' autonomy provided by institutional independence.[161] The professional autonomy afforded to AWRE was rarely under threat; this allowed its leadership not only to focus on the technical aspects of the programme but also the managerial aspects needed to attract and retain staff. Yet Aldermaston's relationship

[153] Hymans, (2012), p.44-50 & Ouagrham-Gormley, (2012), p.91
[154] Hymans, (2012), p.41-3
[155] Ibid., p.133
[156] Narang and Miller, (2018), p.70
[157] Saunders, (2019), p.156
[158] Ibid., p.161
[159] Ibid., p.167
[160] Ibid., p.175
[161] Ibid., p.175

with Whitehall was not flawless. AWRE experienced varying degrees of oversight or delegation afforded to it by the government. Assertive government control imposed strict secrecy and fiscal limitations that often hampered Aldermaston's efforts. Conversely, too much institutional autonomy impaired the communication of knowledge management concerns. The challenge of striking the correct balance was an issue that the British government never fully resolved between 1947 and 1993, as demonstrated by ongoing institutional reforms.

Secrecy

As indicated in the explicit knowledge section, nuclear weapons institutions have routinely established impermeable cultures of secrecy.[162] This can be imposed to avoid detection in cases of proliferation. One manifestation of strict secrecy applied to nuclear weapons programmes is physical dispersal. Ouagrham-Gormley observes that dispersal disrupts "knowledge transmission belts" (thereby creating knowledge "circuit breakers"). Ouagrham-Gormley cites Iraq's WMD programmes, which were forced to locate facilities across the country to avoid detection, thereby halting progress.[163] Ouagrham-Gormley also analyses how Aum Shinrikyo's chemical and bio-weapons programmes were also subject to "multiple interruptions" which inhibited their efforts.[164] Ouagrham-Gormley therefore concludes that "for covert programs fearful of detection, the task is made more challenging as the imperatives of maintaining covertness directly contradict the requirement of efficient knowledge use and production."[165]

However, even established programmes subject to less stringent forms of secrecy can also be affected. In order to maintain operational security, leadership of a nuclear weapons programme may "compartmentalize" their programme to reduce the chance of information disclosure.[166] This will impede progress by preventing different specialised sub groups from communicating with each other as it can stop the exchange of 'transactional knowledge' as described by Sims.[167] Hymans states that the early efforts of the Manhattan Project were impeded by "General Leslie Groves… [whose] security-minded administrative head tried to impose strict controls about information

[162] Wellerstein, (2010)
[163] Ouagrham-Gormley, (2012), p.91 & p.110
[164] Ibid., p.101
[165] Ibid., p.113
[166] Ibid., p.91
[167] Sims, (2007)

exchange within the project."[168] Westwick substantiates this claim by providing the example of how "coordination… [was hampered between] different fast-neutron cross-section studies obtained by far-flung experimental groups."[169] Similarly, this thesis highlights how Britain's training of new nuclear weapons specialists in the late 1950s was restricted by the 'need to know' principle even within a single site.[170]

Even beyond preventing an adversary access to information, secrecy appears to persist as a culture at nuclear weapons related institutions.[171] This raises the question – why? Aftergood observes that "secrecy can also protect a fragile [scientific] program from domestic political interference or opposition."[172] This will come at the potential cost of "intellectual stultification and shields corruption or mismanagement."[173] Kampani concurs following his study of India's nuclear efforts, stating that the "fear of loss of agenda control will constitute a secondary incentive to treat the weapon development effort as a black program."[174]

However, the mechanism by which secrecy interacts with potential mismanagement is complex. As Aftergood notes, secrecy by its nature produces differentials in knowledge between those who have access to information compared to those that do not.[175] This will be felt most acutely when non-technically informed civil servants and politicians interact with scientists from weapons programmes; pre-existing differentials in knowledge could be further exacerbated by mechanisms that purposely hinder inquiry such as official secrecy. Given this interaction is inevitable as part of policy making in regards to CBRN programmes, Balmer believes that "scientific advisors cannot be regarded as standing outside of the policy process and injecting a measure of objectivity into the proceedings."[176] After examining the history of Britain's chemical and biological weapons programmes, Balmer notes that "rather than the scientific advisors' authority being grounded in practical demonstrations of the efficacy of biological warfare, a very general and diffuse appeal to scientific authority formed the epistemological underwriting of their advice."[177] The authority of scientists as experts in their respective fields mean that they can have a determining influence on the research direction of a programme. Solly Zuckerman, the UK's chief scientific advisor from 1964

[168] Hymans, (2012), p.32
[169] Westwick, (2000), p.44
[170] See Chapter 3, Role of William Cook
[171] Wellerstein, (2010)
[172] Aftergood, (1999), p.17
[173] Ibid., p.17
[174] Kampani, (2014), p.72
[175] Aftergood, (1999), p.17
[176] Balmer, (2001), p.7
[177] Ibid., p.186

to 1971 believed that "our 'experts' would… inform and persuade their civil servants and military colleagues – not a difficult task – and the idea would then find its way upwards until often as not it reached ministers."[178] Secrecy also enhances the connection between a weapons establishment and influential policy makers, for as Paglen observed for the American F117 programme, secret programmes create their own influential 'geographies' with direct connections to powerful state institutions.[179] Similarly, Balmer also recognises how "[secrecy] does not so much deny knowledge, as it fractures and disrupts the topography of knowledge," thereby creating power imbalances.[180] Secrecy means that decisions can be made without reference to scientific review, government or public scrutiny.

The ability of scientists and officials to utilise knowledge disparities within CBRN programmes is highlighted by Forden, who cites the example of the Iraqi biological weapons programme. Their reliance "on its own mycotoxin experts" led them down a developmental path that was futile from a weapons perspective. Forden concludes that this was because the "program administrators did not have the specialized knowledge that would have allowed them to better evaluate the advice of their most capable experts."[181] Similarly, Kampani observed how "information asymmetries between political leaders and their technical advisors produced less than optimal choices in India's ballistic missile program in [the 1980s]…. The net consequence was that the missiles developed represented the missile development agency's organizational interests and not those of users' potential for deployment and use."[182] As Aftergood notes, rectifying these issues is problematic as "in the best of cases, secrecy undercuts the possibility of peer review and oversight. In the worst of cases, secrecy will be applied far out of proportion to any requirements of national security and will lead to bad policy, sometimes on a large and expensive scale."[183]

Heterogeneous Engineering

When studying the origins and adoption of technologies, authors such as Law and Mackenzie do not view physical artefacts as being devoid of a social or political context.[184] First used by Law, the

[178] Zuckerman, (1989), p.390
[179] Paglen, (2010), p.769
[180] Balmer, (2006), p.695
[181] Forden, (2007), p.95
[182] Kampani, (2014), p.119
[183] Aftergood, (1999), p.21
[184] Law, (1987) & MacKenzie, (1990)

concept of heterogeneous engineering refers to participants in the design and construction of a technology taking into account a range of considerations beyond the purely technical, including the "social… economic, and… political."[185] Flank and MacKenzie have both observed that nuclear weapons institutions vie for access to resources and political influence within a dynamic political environment and have to frame their technical solutions accordingly in order to satisfy the concerns of policy makers.[186] This can involve a more active process, where "the heterogeneous engineering required from those pushing a new technology is the creation of the sense of a need for that technology. A radically new device does not find a market readymade: That market has to be constructed."[187] This can manifest in constructing threats that require solutions. Balmer's work on biological warfare research in Britain highlights how experts define the imminence and severity of risks by leveraging their authority within their field. Therefore, Balmer believes that "risk can be regarded as a social construct."[188]

From this perspective, arguments about risk must be viewed critically. An extreme example analysed by Vogel was a biosecurity experiment called 'Project Bacchus.'[189] In 1998, the US Defence Threat Reduction agency ostensibly tasked "about four" non-expert individuals to create an anthrax simulant from commercially available equipment. Vogel highlights how the agency had in fact tasked between seven and eight people onto the project, all of whom worked together previously, several of them having prior biological weapons expertise.[190] Vogel states that the fact that "these caveats were not included as part of the technological threat narrative emanating from this project…is striking."[191] Awareness of the ability of institutions to 'sell' risks to further their interests also coloured the response to FOGBANK by some commentators. The NNSA communicated its inability to reproduce FOGBANK when the possibility of replacing the US nuclear arsenal with new Reliable Replacement Warheads was under consideration.[192] This led some commentators to believe that highlighting knowledge loss was an effort to "argue that Life Extension doesn't work, so a new warhead is needed" or "emphasizing the need for further maintenance."[193] Emphasising the importance of tacit knowledge certainly deflected the US Government's Accountability Office's belief

[185] MacKenzie, (1989), p.189
[186] Flank, (1993) & MacKenzie, (1990)
[187] MacKenzie, (1989), p.205
[188] Balmer, (2001), p.7-8
[189] Vogel, (2013), p.41-43
[190] Ibid., p.42
[191] Ibid., p.43
[192] Gusterson, (2008), p.554-555
[193] Ainslie, (2008) & Wellerstein, (2012)

that cost overruns and delays were the result of "ineffective [implementation of] risk management," such as the NNSA's failure in attempting to develop alternative materials sooner.[194]

The suggestion by MacKenzie and Spinardi that nuclear weapons could become 'uninvented' through tacit knowledge loss has also been reinterpreted in this light. Sims and Henke suggest that "the argument the nuclear weapons community made about tacit knowledge in the 1990s served a rhetorical purpose. While it may have accurately described Cold War weapons knowledge, it also served to make the case that weapons testing and production should continue."[195] Hendry and Taylor concur, stating that "nuclear officials have rhetorically cast themselves as guardians of nuclear resources… [to] successfully defend themselves against undesirable change.[196] In adapting to the post-Cold War environment, Sims and Henke characterised the range of rhetorical and technical solutions (such as either Stockpile Stewardship or Reliable Replacement Warheads) as a process of "socio-technical repair," where credibility in nuclear weapons was reinterpreted through new perspectives on knowledge management.[197] Nonetheless, the "scepticism" displayed by nuclear weaponeers in resisting the role of 'black boxing' nuclear weapons design through the use of nuclear simulations was a form of heterogeneous engineering, where skill itself was used to potentially justify ongoing nuclear weapons testing and design.[198]

This thesis demonstrates that concerns over nuclear uninvention are not new. From the outset of the British nuclear weapons experience, establishing a suitably sized skilled workforce had proven difficult and there were concerns over the institution's ongoing sustainability. This fragility was based on their own understandings of the impermanence of tacit knowledge, even if not expressed in those terms. By concerning themselves with the social aspects of retaining and recruiting staff with enough tacit knowledge to undertake nuclear weapons work, Aldermaston's administrators were heterogenous engineers. This meant that at times, research programmes and weapons work was advocated for to resolve social problems relating to staffing, rather than for their direct technical output.

This is not to suggest that the bodies or individuals had anything other than their conception of promoting the national interest in mind as some authors have previously implied.[199] As the individuals involved believed in nuclear deterrence, ensuring the arsenals continuation through

[194] US Government Accountability Office, (2009), p.19-20
[195] Sims and Henke, (2012), p.330
[196] Taylor and Hendry, (2008), p.303
[197] Ibid., p.324
[198] Taylor and Hendry, (2008), p.335 & Gusterson, (2008), p.558
[199] Miall, (1987), p.15 & p.58-59 and McLean and Beyer, (1987), p.118

raising what they perceived as risks to its continuation was entirely consistent with a deterrence based perspective. As will be seen, the repeated internal programmes attempting to address these issues proves the earnestness of belief in the problem. However, premising their arguments in a conception of tacit knowledge made them inherently hard to challenge by external parties – nobody else was qualified (and often not permitted) to scrutinise the level of staffing required by Britain's nuclear establishment. As resourcing the nuclear weapons establishment often had to compete with other policy priorities, this thesis proposes that the conscious decision to highlight the possibility of 'uninvention' through tacit knowledge loss was used to promote an institutional interest rather than a 'parochial' one. In this regard, tacit knowledge-based arguments were a powerful and hard to contest tool for the establishment's heterogeneous engineers in securing further programmes.

Oversight and Autonomy

How do governments ensure they receive balanced technical advice on nuclear matters when there is often only a single institution qualified to provide it? When conducting oversight or exerting their will, governments must contend with information asymmetries and possibly asymmetries in preferences. These challenges form the core of principal-agent theory, a frame of analysis used by social scientists to assess how principals (governments) induce action from their bureaucracies (agents).[200] For nuclear weapons decisions, Kampani's study of India's nuclear programme argues that isolated nuclear "epistemic communities" pose "classic principal-agent problems" for decision makers.[201] These include how principals are limited by "cognitive problems of 'bounded rationality' as well as their agents' domain expertise. Furthermore… agents constitute the permanent state. They are usually the best informed about how bureaucratic processes work within their specific agency and the state in general."[202] Kampani demonstrates that internal secrecy and these principal-agent problems "cocooned Indian decision-makers in a regime of relative ignorance" and allowed interested parties such as nuclear scientists to influence doctrine.[203] In terms of failure to implement policy, Braut-Hegghammer has shown that principal-agent problems contributed to Saddam's failure to convince international inspectors that Iraq was disarming due to misinterpretation of the Baath regime's publicly stated intentions.[204]

[200] Miller, (2005), p.203
[201] Kampani, (2014), p.43
[202] Ibid., p.72
[203] Ibid., p.258
[204] Braut-Hegghammer, (2020), p.88-89

Within this principal-agent framework, how do governments determine when weapons institutions are genuinely in danger of losing skills and need new research programmes? This is a near insurmountable challenge. Polanyi initially fashioned tacit knowledge as an argument to avoid the central planning of science.[205] Only those already within the nuclear weapons community will be qualified to pass judgement. In terms of external attempts, Carrigan acknowledges that "measuring the impact of tacit knowledge on a nuclear weapons programme (or any endeavour, for that matter) is an inexact science."[206] Kampani recognises that standard approaches to overcoming the principal-agent problems are not applicable as "the covert nature of most weapon programs makes the institution of transparency, information availability and multiple agent competition difficult."[207]

In terms of alternate approaches, the existing literature would suggest that asserting oversight would involve greater regulation over the relationships between key advocates of the weapons establishment and policy makers. MacKenzie states that "weapons system developers have often to spend as much time constructing and maintaining their relationships to human actors (politicians, industrialists, senior officers, the multifarious forms of 'bureaucratic politics') as they do forging physical artefacts."[208] As noted in the section on secrecy, when it comes to discussing weapons policy issues, these relationships tend to be unequal due to the inherent discrepancies in expertise enjoyed between practitioners and policy makers.

Changing the institutional relationship between a weapons establishment and the government appears to be a key mechanism by which their interactions are controlled. Spinardi has observed a trend to reduce the "influence" and "independence" within the British nuclear weapons programme so the government could exert more control.[209] The inability to provide oversight is Braut-Hegghammer's alternative explanation of Iraq's lack of progress towards nuclear weapons in the 1980s (compared to Hymans) where "scientists explored technologies that were unlikely to yield results [were pursued and]… constant regime reorganisation made auditing and peer review difficult for the regime and even the IAEC [Iraqi Atomic Energy Commission]."[210] Braut-Hegghammer ultimately argues that the programme was "captured by scientists" due to the deliberate erosion of state capacity by the Baathist effort to 'coup proof' the state.[211]

[205] Collins, (2010), p.148 & Schmidt, (2012), p.194
[206] Carrigan, (2007), p.275
[207] Kampani, (2014), p.73
[208] MacKenzie, (1999), p.186
[209] Spinardi, (1997), p.573-575
[210] Braut-Hegghammer, (2016), p.102
[211] Ibid., p.6-13 & p.71

While an extreme example in an authoritarian state, the history of the British programme as presented by Spinardi also highlights the role of attempting to exert oversight by reforming the relationship between the weapons establishment and policy makers via institutional development.[212] As argued, this corresponded with either empowering a 'mobilised' bureaucracy to provide oversight over AWRE or providing the establishment 'delegated' autonomy.[213] However, Aldermaston was not a passive actor in determining this balance. Although often not as decisive in determining nuclear weapons policy as sometimes portrayed by contemporaries, AWRE was at times able to modulate Saunders' concept of "threat uncertainty." [214] This was done by suggesting the possibility of nuclear weapons 'uninvention' via tacit knowledge loss in order to influence nuclear weapons choices and moves towards greater institutional autonomy. This raised principal-agent problems in the question of the level of autonomy afforded to scientists influencing their input into nuclear weapons decisions.[215] How Britain incorporated the policy suggestions and heterogeneous engineering of its nuclear weapons establishment on the basis of its knowledge management concerns and then altered the level of autonomy afforded to Aldermaston via institutional reform forms the basis of this study.

Summary

In conclusion, this chapter presented the research problem and research question of this thesis, which seek to explore the enduring knowledge management problems encountered by nuclear weapons institutions. Britain was selected as an ideal case study as it highlights the persistent difficulties in identifying and communicating the extent of a nuclear weapons establishment's knowledge management needs. In constructing a theoretical framework and reviewing the existing literature, a range of knowledge management concepts drawn from the Science and Technology Studies field that are relevant to nuclear weapons development were analysed. It was argued that explicit knowledge is insufficient for all but the most basic nuclear weapons programmes. Examples demonstrated the necessity of tacit knowledge for a functional advanced weapons programme. However, as these skills are both retained by individuals and held on a collective level, the continual propagation of this knowledge assisted by the effective

[212] Spinardi, (1997), p.573-575
[213] Saunders, (2019), p.175
[214] Ibid., p.172
[215] Ibid., p.174

management of a nuclear weapons establishment is also essential. This is complicated by the intervening role of secrecy and the tendency of weapons establishments to promote their own institutional interests which exacerbate principal-agent problems. How governments ensure effective knowledge management while resisting heterogeneous engineering through institutional development will be explored further through an examination of Britain's nuclear programme.

Chapter 2: Methodology

Introduction

As demonstrated in the theoretical framework, different approaches to knowledge management and leadership style have been argued in various studies to be key variables that have helped or hindered nuclear weapons programmes. However, it has also been demonstrated that nuclear weapons institutions engage in heterogeneous engineering to further their institutional interests. Having presented a conceptual framework of factors based upon knowledge management concepts, this study establishes how an analogous sense of these concepts was developed within the British nuclear weapons project, how attempts were made to rectify knowledge management issues internally, how any outstanding concerns were communicated with policy makers and how or if they affect the outcome of nuclear policy decisions. This chapter will present the reasoning behind the selected methodology, the processes involved and the areas that have been highlighted by the existing literature that will be further examined within each case study. It will be determined that process tracing applied to case studies will be the most suitable method for investigating the impact of knowledge management. The choice of studying the British nuclear programme will be justified in terms of allowing for a detailed analysis of a programme where it is evident that repeated organisational change reoccurred to address knowledge management issues.

Method

Why Qualitative?

How best to research knowledge management's effects on a nuclear weapons establishment? As suggested by Bennett and Elman, qualitative methods are ideally suited for considering these types of problems as they are fit for "studying complex and relatively unstructured and infrequent phenomena that lie at the heart of [social science research]."[1] Questions of knowledge management and nuclear weapons establishments fit within this category as although the contemporary arguments traced by this thesis were related to technical matters, the arguments

[1] Bennett and Elman, (2007), p.171

were contested and resolved within a complex social and political system. Tracing the effectiveness of these arguments fits within a Social Construction of Technology framework, where "the success of a technology depends on the strength and size of the groups that take it up and promote it."[2] As MacKenzie detailed with his account of the development of missile guidance technologies, there is nothing preordained that required a certain technological path to be chosen.[3] Instead, he states that it was instead a "complex process of conflict and collaboration between a range of social actors including ambitious, energetic technologists, laboratories and corporations, and political and military leaders and the organisations they head."[4] This is seen within the British nuclear weapons case as the organisational framework and personal connections that the weapons establishments proponents and detractors had influenced the weight of their arguments. Tracing these complex and context sensitive interactions behind this "social process" is something that can only be achieved through a qualitative research approach.[5]

A further factor necessitating a qualitative approach for this research is the intangible nature of the arguments examined. Concepts such as credibility and reliability of nuclear weapons can in one sense be empirically judged through testing, but as Sims and Henke have demonstrated (especially after the CTBT), are subject to flexible expert judgement that can alter due to "discursive, institutional, and material change in the repair of complex sociotechnical systems."[6] The role of expert judgement becomes even more prescient when predicting future 'skill' requirements for maintaining a nuclear weapons arsenal. As will be highlighted, even the most informed Aldermaston administrators were only able to allude to potential future requirements. Administrators consistently called for skills to be retained but could only allude to their special and unique nature, combined with the consequences of their loss rather than precise numbers or requirements. This was because future technical problems were unpredictable and supposedly only resolvable based upon expert judgement and intimate familiarity with the technology. When a definitive figure was placed upon future staff requirements in the 1960s, it proved one of the most contentious episodes in the establishment's history and is covered in detail in Chapter 6. The factors driving staff recruitment and retention are even more unquantifiable, based in perceptions of morale, political support from government and upholding beliefs in the need to retain nuclear arms. Responses to upholding these criteria are quantifiable, but directly comparing staffing figures at Britain's nuclear establishment over time would be meaningless given the fluctuations in production, research,

[2] Sismondo, (2007), p.16
[3] MacKenzie, (1987), p.2
[4] Ibid., p.3
[5] Ibid., p.4
[6] Sims and Henke, (2012), p.324

diversification and the role of automation in work at the nuclear weapons establishment over time. Only through systematic qualitative analysis can a sense be built up of the importance of various processes based upon the attitudes and perspectives provided.

Any attempt to retrospectively gauge a comparable 'quantity' of tacit knowledge within Britain's nuclear weapons institution would likely prove futile. Although Collins' case studies have proven that the effects of the dissemination of tacit knowledge can be observed from institution to institution (and therefore numerically), measuring its accumulation within one locale is problematic.[7] As will be demonstrated, attempting to measure knowledge management issues directly was challenging even for contemporaries and cannot necessarily be divorced from the institutional context they are made within. Nonetheless, the scale, urgency and attention paid to the internal measures taken to resolve knowledge management issues indicate the seriousness with which these problems were treated with.

Given the above merits of a qualitative approach, it is therefore unsurprising that the predominant method used by MacKenzie and Spinardi, Hymans, Braut-Hegghammer, Ouagrham-Gormley or Vogel to present their findings is the use of "disciplined configurative" type case studies.[8] As highlighted by Flank who explored the "reasons and processes" behind the "historical sociology of nuclear proliferation" for India and South Africa, the content of each case study is necessarily primarily "descriptive" as the influences upon a weapons establishment are wide ranging.[9] Hyman's and Montgomery's work are among the few exceptions that attempt to apply qualitative metrics to the intersection of nuclear proliferation and knowledge management, but even then, the majority of evidence that they provide in support of their arguments is qualitative.[10]

Contemporary Terminology

A further benefit of a qualitative approach is that it allows this thesis to tackle the doubly problematic task of transposing a knowledge management framework onto a historic nuclear programme with mismatched contemporary terminology. Although the previous chapter presented multiple subcategories of tacit knowledge to highlight their breadth and relevance to nuclear weapons production, Lynch notes even Collins recognised that "there is no possibility of drawing a

[7] See Collins, (1974) & Collins, (2001)
[8] George and Bennett, (2005), p.75 & Bennett (2004), p.22
[9] Flank, (1993), p.259
[10] Hymans, (2012) & Montgomery, (2013)

bright line between tacit and explicit knowledge…[and that it is] fuzzy at the margins.[11] This is paired with historically ambiguous arguments calling for retention of 'skills' at AWRE. 'Skills' and similar references could wholly or in part refer to the utilisation of explicit concealed or logistically demanding knowledge rather than any tacit dimension. This is hard to entirely dismiss given the nature of the sources. However, this is unlikely; Collins notes that even some tasks that have been presumed to be made wholly explicit via 'black boxing' still require tacit knowledge to contextualise and operationalise.[12] This theme will be returned to in the conclusion as a similar logic has been adopted by AWE since the halt of nuclear testing. Furthermore, as the argument over skill retention matured over time, it incorporated aspects commonly associated with tacit knowledge rather than esoteric explicit knowledge; by 1962, 'skills' were personally embodied and gained via ongoing practice, could easily be lost and were held collectively.[13]

This thesis also highlights the subtle adaptability of the 'skill' retention case as the emphasis on different components of this argument changed with institutional and technological circumstances. AWRE's authoritative appeals to 'skills' as "something mystical and inspirational" that defied easy measurement is directly akin to Polanyi's original conception of tacit knowledge, as explained by Schmidt, as a "deflective construct" to avoid central planning.[14] Although rooted directly in the difficulties encountered by AWRE, the importance of the establishment's contemporary sense of knowledge management for this thesis is in how it was responded to and then used rhetorically to influence policy. This sentiment is agreed with by Lynch, who in examining Collins' typologies, states that "how the claimed reality of tacit knowledge plays out may be more interesting sociologically than the "fact" of whether tacit knowledge is or is not "real" in a particular case."[15]

Process Tracing

To explore how nuclear establishments have responded to their knowledge management concerns, the best available method is what George and Bennett detail as "process tracing."[16] This provides the ideal qualitative method for examining historical case studies as envisaged by this

[11] Lynch, (2013), p.62
[12] Collins, (2010), p.142
[13] See Chapter 5
[14] Collins, (2010), p.148 & Schmidt, (2012), p.194
[15] Lynch, (2013), p.68
[16] George and Bennett, (1997)

thesis. This was due to their forwarded method's ability to explore "causal processes and intervening variables through which causal or explanatory variables produce causal effects."[17]

Mahoney offers specific advice for using theory tracing within the security studies field. Indeed, he offers Tannenwald's study on *The Nuclear Taboo* and Sagan's *The Limits of Safety* as examples of where the method has been applied to nuclear relevant issues.[18] According to Mahoney, process tracing involves ascertaining and testing the intervening mechanisms between cause and effect within historical empirical data.[19] Tannenwald explains that this method can convert "rich historical narrative[s] into an analytical explanation couched in theoretical (rather than empirical) variables."[20] To test the explanatory power of pre-existing theoretical variables, Mahoney recommends one should suggest the evidence one would expect to find if cause X led to effect Y through empirical observations. For example, if a weapons establishment was engaging politicians to acquire more work, one would first have to determine whether this could be linked back to an identified problem with knowledge management at the weapons establishment. If such links cannot be established, then this would strongly indicate that the suggested theoretical variables have little explanatory value.[21]

Alternatively, if these events could be substantiated and a convincing line of argumentation forwarded to link them, this step can be reiterated with any "intervening or antecedent factor[s]" uncovered to find any sequential explanations.[22] These could include the role of contemporary international events or how influential individuals influenced this process. Secondary or tertiary stages are necessary to explain the link between the understanding of knowledge management within a weapons programme and how this translates into changes in nuclear policy. The ability to test for 'sequential explanations' will allow for the assessment of the importance of a range of "intervening" variables such as the role of secrecy, the advocacy of management to policy makers or internal knowledge retention programmes.[23] By inspecting and ordering the role of various theoretical mechanisms rather than just their effects and relative magnitude, an understanding of how the complete process of knowledge management translating into outcomes can be established. By understanding the process by which results are obtained, process tracing assists in the ability to inspect "recurring empirical regularities" or "puzzling outcomes."[24] However, Tannenwald advises

[17] George and Bennett, (1997)
[18] Mahoney, (2015), p.200
[19] Ibid., p.205
[20] Tannenwald, (2015), p.221
[21] Mahoney, (2015), p.207
[22] Ibid., p.205
[23] Braut-Hegghammer, (2016), p.229
[24] George and Bennett, (1997), Mahoney, (2015), p.217 & Collier, (2011), p.824

that the basis of this method remains "good narrative" and that the explicitness of approach "should not become such a fetish that it overwhelms the narrative."[25] Nonetheless, methodological rigour is needed to establish a causal chain between perceived threats to tacit knowledge and efforts to influence nuclear policy. As such, hypotheses are drawn from the secondary literature to highlight mechanisms that demonstrate the recurring phenomenon of knowledge management concerns leading to internal retention measures, heterogeneous engineering and then government reaction.

British Case Studies

As highlighted in the previous chapter, Britain provides an ideal case study for assessing the challenges of knowledge management, as the effort underwent periodic reorganisations in order to improve variables highlighted in the conceptual framework such as tacit knowledge retention (through retaining staff and their 'skills') through greater provision of autonomy or centralisation in order to improve governmental oversight. This means that it is simple to configure the history of Britain's effort into periods that generally relate to programmes of work or major reorganisation. These transitions provide four distinct periods for study. These are:

- High Explosive Research (1947-1952)
- AWRE and Hydrogen Bomb Development (1954-1958)
- Skybolt Crisis to the Polaris Improvement Programme (1960-1969)
- AWRE under the MoD to Contractorisation (1973-1993)

These periods were chosen as each contained new major programmes of work and institutional reorganisation for the establishment. These reorganisations and policy responses were often undertaken to correct the inadequacies of the prior system. Successive governments implemented these changes with a desire to increase the efficiency of the programme by improving knowledge retention, without diverting significantly more material resources to the nuclear weapons establishment.

Therefore, by splitting the history of Britain's nuclear weapons efforts into these periods, this iterative within-case analysis approach allows for the differing outcomes and causes of perceived threats to knowledge management at the weapons establishment to be observed. The discussion, responses to and implemented changes resulting from perceived deficiencies in

[25] Tannenwald, (2015), p.227

knowledge management will provide the core observable manifestations of empirical findings in this thesis. The conclusions of this thesis examine events after 1993 to confirm whether a similar process continues to manifest but cannot comment upon them in the same level of detail due to source limitations.

The commonalities between the cases, in their causes, processes and outcomes will highlight how the discourse and pressures to maintain knowledge management were a persistent and cyclical theme within Britain's nuclear weapons establishment between 1947 and 1993. This thesis will demonstrate that the ability to maintain nuclear weapons and to adapt to potential future defence needs was consistently perceived as being fragile. This stemmed from the early recognised need of maintaining people with specialised tacit knowledge skills through work and thereby educating the next cohort of professionals to sustain the establishment's future. However, as the supply of nuclear weapons work was inconsistent, managers at AWRE/AWE and officials within the Ministry of Defence had to find alternative remedies which could include lobbying for further work for the establishment. How ministers responded to these efforts differed. They either chose to mobilise a consensus around rejecting uninvention or delegated nuclear weapons decision making, thereby empowering Aldermaston's advocates to advance knowledge management concerns.[26] These decisions established the conditions in which the weapons establishment would find itself when staff retention inevitably became an issue once again when a programme of work neared completion.

Approaching the eras chronologically is logical given that each chapter will necessarily be interlinked, as whether the perceived failings of the prior institutional format were realistic, correctly identified and acted upon successfully is debated in the following periods. As will be demonstrated by quoting the concerns of contemporaries, reorganisations were justified on and motivated by concerns to improve elements of knowledge management presented in chapter one, even if not expressed in the same terminology. Additional causal mechanisms (or the lack/weakness thereof) such as the role of influential officials and international events that help explain the outcome are examined. By comparing the causes and outcomes identified in each case study, this allows for an understanding to be developed of how the processes by which knowledge management concerns translate into a pressure to provide further work to a nuclear weapons establishment.

[26] Saunders, (2019), p.175

By grounding analysis around knowledge management issues within the UK's nuclear weapons establishment and how they were resolved within each case, this method can generate hypotheses for each of the identified periods of study. In line with process tracing best practice, the following section will present a brief outline of each of the four case study sections, drawing from the available secondary literature and highlight inferences that will be examined to help understand the process of translating knowledge management concerns into policy actions within the following chapters.[27] For the sake of focusing on the organisation of the programme and brevity, a detailed history centred on technical developments within the UK's nuclear weapons programme is avoided. Technical details will be introduced to the analysis when relevant.

High Explosives Research (1947-1952)

Although Britain first investigated the possibility of fission weapons through the MAUD committee with the assistance of exiled scientists, its efforts became subsumed under the American Manhattan Project.[28] While Britain expected to share in the fruits of the project after the war, the prospects for this occurring diminished over time. As a result, the Attlee government gave approval for the initiation of a nuclear weapons programme on 8th January 1947.[29]

This effort, called High Explosive Research (HER), would be beset by organisational challenges as it proceeded to conduct the proliferation campaign while still forming itself as an institution. Numerous knowledge management issues were encountered such as justifying and diverting enough resources to the project, justifying the programmes' existence, how it should be organised, identifying skill shortages and what could be undertaken to rectify them. It was in this environment that the British nuclear weapons programme developed a culture that emphasised the vulnerability of its skills and knowledge base and a need to campaign amongst the bureaucracy and politicians for the work it received.

In this contested environment, the management of the British nuclear weapons project emerged on an ad hoc basis. Unlike the American effort at Los Alamos, there was initially no single nuclear weapons research institute. While there had been some discussions over whether to integrate nuclear weapons research within the Atomic Energy Research Establishment at Harwell,

[27] Collier, (2011), p.823
[28] Nuclear Weapon Archive, (1)(2007)
[29] Gowing, (1974), p.411-412 & p.442

which had been founded in 1946, this was rejected to keep this 'peaceful' effort separate for political reasons.[30] As the Ministry of Supply and the subordinate Armament Research Department (ARD) were deemed to have spare capacity and relevant infrastructure, the nuclear weapons programme, HER was initially incorporated within these institutions. Both the Ministry of Supply and the ARD were vestigial organisations from the Second World War tasked with producing conventional armaments. Therefore, the organisational structure that William Penney was tasked to lead from 1947 was unique for both the geographic distribution of its work and its complete ignorance of nuclear fission related science. While none of the staff that worked within the HER project had prior nuclear weapons work experience (save Penney himself), many of those selected for HER work from Fort Halstead and Woolwich Arsenal had relevant conventional weapons development expertise which allegedly proved vital to the progress of the project.[31] Arnold claims that without the Armament Research Department, "Penney could never have built up a nuclear weapons team so quickly."[32]

Nevertheless, situating the HER project within the scientific civil service was a move that was retrospectively heavily criticised by Lord Cherwell. He claimed that it was one of the central reasons why the Soviets had developed their bomb first.[33] Overall, this claim is rejected by Gowing, who states that "the manpower problems [for manning a new agency] would have made the task impossible."[34] Yet the institutional framework within which the HER programme found itself working within did have several disadvantages. While well established, the civil service framework was allegedly inflexibly bureaucratic and responded poorly to the sudden demands of the nuclear project on seemingly minor issues of staff housing and transportation.[35] Chief amongst these matters were the civil service pay restrictions, which constantly effected Penney's ability to attract more staff.[36] After Operation Hurricane, Cherwell would eventually persuade Churchill of the merits of moving the programme to a free standing corporation: the UK Atomic Energy Authority, to free it from these restrictions.

While the HER project was conducted before the principle of non-proliferation had been normalised, it was operated in strenuously applied secrecy.[37] In addition to procurement and

[30] Cathcart, (1994), 59.4/673: The plutonium from the first reactor piles reactors had been designated for weapons purposes.
[31] Cathcart, (1994), 640/673 & Arnold and Pyne, (2001), p.73
[32] Arnold and Pyne, (2001), p.74
[33] TNA, CAB129/56, Cabinet - Atomic Energy Organisation, 25/10/1952
[34] Gowing, (2) (1974), p.445
[35] Lord Cherwell, HL Deb 05 July 1951 vol. 172 cc670-9
[36] Cathcart, (1994), 139.6/673
[37] Ibid., 63.9/673

communication delays, secrecy further compounded the unattractive conditions for HER staff. Career minded scientists could not publish their work and instead worked at Harwell.[38] Penney bitterly complained that "such men do not wish to work in the top-secret atmosphere essential to HER."[39] When the effect of secrecy was combined with the separation from the ARD in 1950, it produced a near existential threat to the programme. The 'need to know' basis of the HER project had left it with minimal cabinet level political support and its relative prioritisation was delegated to the Chiefs of Staff.[40] According to Cathcart, Tizard nearly successfully lobbied the chiefs into deprioritising HER in favour of conventional weapons research.[41] Without the determined efforts of Lord Portal, this would likely have had the effect of denuding HER of scientists at a vital juncture which could have endangered the programme.[42]

How well this initial effort was handled in terms of knowledge management is in dispute when comparing the analysis of MacKenzie and Spinardi to Hymans.[43] Hymans, who focuses on governmental capacity and professionalism, quotes Gowing who states that "[Britain's] early atomic project's success was remarkable and possibly unique."[44] In contrast, MacKenzie and Spinardi assert that the United Kingdom's effort to produce nuclear weapons "turned out not to be straight forward" due to the limited tacit and explicit knowledge retained from the Manhattan programme.[45] They cite how while it was initially planned to be completed with a "staff of less than 400, covering reactor development as well as weapons work. By the start of 1952, however, the program's "nonindustrial" staff numbered over 5,000, with more than 1,000 of these devoted to the weapons work alone. Furthermore, "the five years it took to make the intended copy was longer than it had taken to make the original."[46]

In sum, the HER project successfully overcame a range of serious managerial conditions to successfully detonate its first device in 1952. Its ability to do so is often credited to effective management and leadership from senior scientists despite the "machinery of government …[being] diffuse and ill-suited to ensure strong central direction or coordination."[47] This may be because politicians "left most of the technical issues involved in the construction [of the bomb] to be

[38] Arnold and Pyne, (2001), p.74
[39] Cathcart, (1994), 293.3/673
[40] Ibid., 341.5/673
[41] Ibid., 281.9-288/673
[42] Gowing, (2) (1974), p.451
[43] Hymans, (2012), p.33-34 & MacKenzie and Spinardi, (1995), p.70-71
[44] Hymans, (2012), p.34
[45] MacKenzie and Spinardi, (1995), p.71
[46] Ibid., p.71
[47] Gowing, (1) (1974), p.4

resolved by those managing the project."[48] However, the effort appears to have been more strenuous than initially predicted and Cherwell's reforms of the HER project into the UKAEA indicates that there was contemporary unease with how the nuclear weapons programme had been organised.

Hypotheses

From the above reading of the secondary literature, it can be inferred that:

- Placing the HER project within ARD initially allowed for the prompt assembly of an embryonic nuclear establishment with experienced staff.[49]
- A lack of representation on research committees threatened HER's continuation due to reprioritisation compared to conventional arms projects.[50]
- Secrecy and inclusion within the civil service limited the recruitment of necessary staff. [51]
- The creation of the United Kingdom Atomic Energy Authority was the result of the problems experienced during the HER programme.[52]

AWRE (1954-1958)

While Britain successfully detonated its first nuclear device with Operation Hurricane in October 1952, the United States conducted its first thermonuclear test in November 1952. Given that the UK's nuclear weapons programme had been in part instigated to 'keep pace' with US nuclear weapons development in order to resume strategic cooperation, it was evident that the UK would have to develop an indigenous hydrogen bomb programme.[53] However, neither Cherwell nor Penney had been keen on a premature push for the development of hydrogen weapons as Aldermaston's capacity was already stretched delivering Blue Danube devices.[54] While minimal activity on developing hydrogen weapons occurred in the next two years, March 1954 saw the detonation of the US's Castle Bravo test, which showed that the technology was viable. Cherwell had increasingly agitated for hydrogen bomb development since 1953 and Penney had become more

[48] Simpson, (1986), p.62
[49] Arnold and Pyne, (2001), p.74
[50] Ibid., 293.3/673
[51] Cathcart, (1994),Ibid., 139.6/673
[52] Lord Cherwell, HL Deb 05 July 1951 vol. 172 cc670-9
[53] Arnold and Pyne, (2001), p.37
[54] Simpson, (1986), p.102-103

confident in the rudiments of thermonuclear technology by early 1954.[55] Following their advice, Churchill approved the development of a UK hydrogen bomb project in July 1954.[56]

This large intake of work came at an inopportune time for Aldermaston. While the organisation had successfully developed fission weapons, short term expedients in terms of management had been taken to deploy them as soon as possible. Attempting to correct these issues in 1954 had partly motivated the reorganisation of the weapons effort under the UKAEA as the AWRE, advocated by Lord Cherwell.[57] While many of the reforms appear to have been needed rationalisations from a management perspective, they appear to have introduced employment uncertainty when it was least needed as staff were given two years to decide if they were to stay at AWRE. [58] Staffing issues, the perennial problem at Aldermaston, appear to have been further compounded by the rise of the anti-nuclear movement.[59] According to Arnold, as staff recruitment matched wastage, AWRE "was displaying classic symptoms of an approaching nervous breakdown."[60]

How AWRE was able to recover from this nadir in early 1954 and go on to produce thermonuclear devices by November 1957 remains a theme under-developed in the secondary literature. Simpson credits "dynamic management and leadership" at Aldermaston for the rapid delivery of a thermonuclear device from cabinet decision to delivery.[61] Both Arnold and Pyne and Jones credit this recovery largely to the personal influence of William Cook, a senior naval scientist seconded to the programme in September 1954.[62] Cook took over management responsibilities from Penney who was freed to work on more scientific work. Notably, Arnold and Pyne detail how Cook dismantled the culture of compartmentalisation at Aldermaston by instituting Weapons Development Policy Committee meetings where inter-specialisation discussion was encouraged.[63] How staffing issues were resolved is not sufficiently explained. Extra resources dedicated to the new programme likely enabled a new round of recruitment to replace previous deficiencies.[64] Nevertheless, McIntyre highlights industrial accidents at AWRE as an indication of an ongoing lack of trained staff.[65] While not significantly acted upon in this time frame, this chapter will highlight the

[55] Arnold and Pyne, (2001), p.39-41
[56] Churchill, (1954)
[57] TNA, CAB129/56, Cabinet - Atomic Energy Organisation, 25/10/1952
[58] Arnold and Pyne, (2001), p.75
[59] Ibid., p.76
[60] Ibid., p.76
[61] Simpson, (1986), p.104
[62] Jones, (1)(2017), p.32 & Arnold and Pyne, (2001), p.76
[63] Arnold and Pyne, (2001), p.80-82
[64] Ibid., p.79-80
[65] McIntyre, (2009)

promise of providing a diversified research portfolio. This offer was the main incentive to staff who increasingly began to identify themselves with the specialised skills they held and were concerned about their future career prospects.[66]

Despite problems with recruiting and retaining staff, AWRE was testing thermonuclear devices by May 1957. Although the 1st Grapple test was considered a failure, shortcomings had been rectified by the Grapple Y series of tests in 1958. Notwithstanding the disorganisation that had reined in 1954, AWRE had developed a thermonuclear capability before the imposition of an international test moratorium which they had been perpetually threatened with by the Foreign Office.[67]

Further research needs to be conducted on how these processes are interconnected and how the challenges faced by the UKAEA were overcome. While the answer may be a matter of resourcing, limited information is available on how Cook improved the management at AWRE. Questions regarding AWRE's 1953-4 plight have been posed by Arnold and Pyne, but insufficiently answered: for instance, they ask "whether the setting up of [UK]AEA at this stage was a wise, if difficult, measure to meet new circumstances and needs, or an untimely disruption at a critical period", but they do not provide an answer.[68] As Walker notes from his recent article on this era of British nuclear developments, The National Archives remains an "untapped source, on the nuts and bolts of the British nuclear weapons program."[69]

Hypotheses

From the above reading of the secondary literature, it can be inferred that:

- Seemingly imminent agreement on a nuclear test moratorium helped expedite the thermonuclear programme.[70]
- The transition to the UKAEA negatively affected AWRE staffing.[71]
- Cook improved information sharing at Aldermaston to the benefit of the project.[72]

[66] TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954
[67] Arnold and Pyne, (2001), p.109
[68] Ibid., p.75
[69] Walker, (2012), p.191
[70] Arnold and Smith, (2006), p.82-83
[71] Arnold and Pyne, (2001), p.75
[72] Ibid., p.80-82

- Staff members had begun to recognise the tacit knowledge that they held by calling themselves 'weaponeers.'[73]

Polaris Improvement Programme (1960-1970)

The conventional narrative that explains the origins of the Polaris Improvement Programme starts from the resumption of strategic cooperation with the US under the 1958 Mutual Defence Agreement, following the British hydrogen bomb programme. The agreement led to a plan wherein the UK would purchase Skybolt missiles to augment its deterrent, but President Kennedy cancelled the programme in the face of technical deficiencies. Because of the subsequent 1962 Nassau Agreement, Prime Minister Macmillan secured the UK's purchase of the Polaris missile system. While Polaris was adequate for US purposes, there was a growing awareness of its warheads' vulnerability to interception from Soviet Anti-Ballistic Missile (ABM) systems. Whitehall was becoming increasingly concerned that American extended deterrence would fail in a nuclear scenario where only the United Kingdom was targeted as unhardened British Polaris warheads would be blocked from striking Moscow. [74] While the US in 1967 passed on developmental ideas on hardening Polaris missiles to their Antelope standard to the British, the US-Soviet negotiations on an ABM treaty placed the possibility of future technological transfers in jeopardy.[75] This factor, combined with the potential insufficiency of the Antelope upgrade when combined with the limited British missile inventory led to the perception of the necessity of an indigenous upgrade programme.[76] Therefore, in 1967, the MoD directed AWRE to begin searching for technical solutions.[77]

However, Stoddart presents a different interpretation of events leading to the acceptance of paper studies towards improving Polaris. In the 1960s, Aldermaston found itself again in a staffing crisis where a lack of new projects and funding was leading to a "brain drain."[78] Civil servants were informing ministers that unless a programme of Polaris improvement was initiated at AWRE, then Britain would be unable to maintain an independent credible deterrent.[79] Such a view was endorsed

[73] Ibid., p.xiii
[74] Baylis and Stoddart, (2003), p.126
[75] Ibid., p.131
[76] Ibid., p.129
[77] The National Archives, (2005), p.9
[78] Stoddart, (2014), p.159
[79] Ibid., (2014), p.159

by the Kings Norton Inquiry and led to a state of interminable paper studies from 1967 onwards at the cost of £4 million a year as the Wilson Labour government stalled on approving the development of a Polaris Improvement Programme, that would eventually become the Chevaline system.[80]

This chapter will trace the history of this theme, highlighting how the origins of the Polaris Improvement programme lay within the rapid expansion of the weapons establishment in the late 1950s with Britain's thermonuclear programme. This was followed by a change of policy under the second Macmillan administration which was intent on making considerable defence spending reductions. Within this political environment, AWRE strongly made the case for further developmental programmes on the grounds of retaining skills. Although it appeared that significant reductions would be made at the weapons establishment, the cancellation of Skybolt required Aldermaston to develop interim weapons and a warhead for Polaris. Despite this work and measures by the Wilson government to provide civilian diversified research to AWRE, select officials were making the case in 1966 onwards that new work would again have to be provided to keep the establishment viable.

Given that elements of Wilson's first administration advocated unilateral nuclear disarmament and were intent on preventing any further development of nuclear weapons, it was inevitable that AWRE's efforts to secure further work would be contested. This chapter will examine the prelude to and findings of the Kings Norton Inquiry. The panel had been instituted to determine how few staff could be employed at Aldermaston to keep it viable. While it was expected that this would provide justification for further economies, it will be demonstrated that the results further enabled the progression of work on Polaris Improvement based on retaining tacit knowledge.

Within this contested political environment, the instrumentality of select civil service figures in forwarding the necessity of Polaris upgrades is agreed by contemporary commentators, such as McIntosh and Pyne.[81]For example, William Cook, who was now Chief Scientific Advisor to the MoD and former AWRE deputy director "proved to be a formidable White-hall operator" and "fought Zuckerman [Polaris Improvements main critic] at a political level."[82] Victor Macklen, Cook's deputy and from the UKAEA, was variously characterised as "Mr Nuclear" or a "nuclear freak" and accused of being "unnecessarily aggressive" when advocating for Chevaline. [83] As McIntosh makes clear, "the role of the nuclear scientists is… vital to understanding the momentum of the Chevaline project."[84]

[80] Grant, (2011), p.170
[81] Pyne, (2007) & Mcintosh, (1990), p.104
[82] Spinardi, (1997), p.561
[83] Miall, (1987), p.58-59 & Jones, (2)(2017), p.141
[84] Mcintosh, (1990), p.104

This chapter will trace the role that the limited oversight provided by the Ministry of Technology, UKAEA and Cabinet Office afforded both the Ministry of Defence and AWRE in formulating their arguments in favour of further nuclear weapons developments, further protected by official secrecy.

The 1960s therefore represents the zenith of AWRE's operational independence and marked political influence. However, the questionable strategic logic of Chevaline and immense resources devoted to the programme would later be criticised. How such a dynamic developed is debated and will require further research: McIntosh suggests the political need to reach technological parity with the US was a driver, combined with professional pride by AWRE in seeking the best indigenous capability regardless of costs.[85] Campbell offers a more cynical assessment in that "if Chevaline had not gone ahead in the early 1970s, the Aldermaston nuclear weapons design staff would have had nothing to do."[86] Even Spinardi, who argues against the overall proposition that nuclear weapons development in the UK was driven by scientists concedes that Chevaline was the exception.[87] He goes as far as to say that "the Chevaline case suggests that too much discretion over research aims may have a Frankenstein effect."[88] Through process tracing, this chapter will largely agree by demonstrating that the initial justification for a Polaris Improvement Programme was premised on the need to retain knowledge within the establishment rather than an operational justification for the weapons themselves.

Hypotheses

From the above reading of the secondary literature, it can be inferred that:

- AWRE cited possible nuclear weapons 'uninvention' in 1960-1962 to argue against staffing reductions. [89]
- Civilian diversified research failed to stop concerns over a 'brain drain.' [90]
- The Polaris Improvement Programme was forwarded to retain expertise at AWRE.[91]
- The Kings Norton inquiry was unable to effectively determine AWRE's staffing needs.[92]

[85] Ibid., p.104-105
[86] Campbell, (1985), p.12
[87] Spinardi, (1997), p.573
[88] Spinardi, (1993)
[89] Stoddart, (2014), p.159
[90] Ibid., p.159
[91] Mcintosh, (1990), p.104
[92] Moore, (2004), p.D-8

- The Ministry of Technology and UKAEA failed to contribute effective oversight over AWRE.[93]

Kings Norton to TASM (1970-1993)

This chapter will trace the developments that unfolded after the conclusion of the Kings Norton Inquiry until the contractorisation of the establishment in the 1990s. Given that many of the documents relating to this period remain classified, it is the least well covered by secondary literature. Nonetheless, many of the same themes and processes that have been identified in previous periods can still be observed in action with new archival information that has recently been released.

The first development that this chapter will trace is how, in the aftermath of the Kings Norton Inquiry, government ministers realised the need for AWRE to face greater oversight. This is evidenced by how in 1973, the AWRE was transferred from the UKAEA (representing a clear organisational break from the prior 1954 settlement) to the MoD's Procurement Executive. Spinardi claims that the shift from internally appointed AWRE directors to "imposing career civil servants [was done] in the hope that they would be more responsive to the interests of Whitehall, and not of the nuclear scientists," but he provides no further evidence.[94] Whether this policy represented an immediate improvement is questionable, given the limited capacity of the MoD Procurement Executive to provide oversight.[95] One significant effect of this move was to remove the AWRE's director's discretionary sponsorship of research projects, thereby curtailing the chances of self-initiated programmes.[96]

After the gradual reduction of staffing levels at the establishment, AWRE experienced a series of safety incidents in 1978 that further disrupted Chevaline production and created a sense of crisis.[97] It will be shown that the institutional changes implemented after Kings Norton were in part responsible for this process. Furthermore, it will be demonstrated that safety concerns in 1978 accelerated pre-existing trends of skilled industrial labour leaving the establishment to the extent that both Labour and Conservative governments were forced to enact measures to maintain the viability of the establishment. The limitations on the capacity of the weapons establishment would

[93] Spinardi, (1997), p.561
[94] Spinardi, (1997), p.573
[95] Theakston, (1999), p.229
[96] Spinardi, (1997), p.573
[97] Stoddart, (2)(2014), p.252

then influence the Thatcher government's decisions over Trident, nuclear cruise missiles and replacement of WE-177.

Through examination of newly released files, it will be found that staffing recruitment and retention problems would continue to be prevalent issues AWRE throughout the 1980s. Poor morale, pay and strikes led to the concern that Trident production would not be fulfilled on time, thereby endangering other AWRE development projects. While measures were implemented to rectify these issues in the short term, contractorisation was seen by the Thatcher government as being able to provide a sustainable basis for the establishment outside of the civil service. The commonalities between these arguments and those that led to the foundation of the UKAEA will be highlighted, further emphasising the cyclical nature of the attempts to balance control and institutional freedom for the nuclear weapons establishment.

This chapter will also demonstrate AWRE's awareness of the need to retain its own institutional knowledge through methods other than a continual supply of developmental work. This initially manifested after the Kings Norton inquiry with the start of 'trickle' production, where a small number of warheads were broken down and reassembled each year so that skills would be routinely practiced. In addition, growing concern over the possibility of a comprehensive test ban treaty led AWRE exploring ways of transitioning from a model based upon socially retained knowledge on nuclear weapons development to a greater emphasis on generating new explicit knowledge through simulating nuclear weapons physics in laboratory conditions.

The chapter will conclude by tracing the heterogeneous engineering of the Tactical Air Surface Missile (TASM), a nuclear system intended to replace the aged WE-177. While the end of the Cold War virtually guaranteed that no new developments would proceed, it will be shown that similar arguments over the fragility of skills at the weapons establishment and the need for continuous development were cited in an attempt to acquire authorisation of the project.

Hypotheses

From the above reading of the secondary literature, it can be inferred that:

- AWRE's transition to the MoD was an attempt to provide greater oversight of the establishment.[98]

[98] Spinardi, (1997), p.573

- Reductions to AWRE under the MoD contributed to the plutonium incidents in 1978.[99]

Although the secondary literature on this more recent era is limited, the chapter will derive from primary sources that:

- AWRE's limited capacity in the 1980s was the result of loss of staff and skills and this in turn impacted nuclear policy.
- AWRE instituted internal programmes to retain tacit knowledge explicitly in response to challenges raised in the Kings Norton inquiry.
- Contractorisation was justified on providing AWE the autonomy allegedly needed to manage staff effectively, intended to save money and improve knowledge retention.
- That the possibility of 'uninvention' was used to justify TASM in the 1990s.

Conclusion

In conclusion, this chapter has presented how process tracing will be used to highlight the cyclical causal mechanisms for how the weapons establishment's concerns over knowledge management led to heterogenous engineering. Britain was selected as providing the best series of case studies as it has repeatedly reformed the organisation of its weapons institution to improve knowledge management. Furthermore, debate exists over the role of institutional interest in determining its weapons developments. A brief history of each era selected to be examined as a case study was presented which summarised the existing literature on the period. Several hypothesised mechanisms suspected of being in operation for each period were provided that will be tested in the subsequent chapters. By studying the process by which AWRE/AWE has attempted to influence weapons policy by asserting its own fragility, this thesis demonstrates that warnings over 'nuclear uninvention' were not new with the end of the Cold War, but a powerful mechanism that could influence weapons policy in the case of Britain.

[99] Stoddart, (2)(2014), p.252

Chapter 3: Fighting for HER (1947-1952)

Introduction

This chapter examines the initial operation of Britain's nuclear weapons establishment. As detailed in the framework, a historical narrative will be constructed through a series of mechanisms that shows how the early nuclear weapons programme became aware of its own knowledge management requirements after experiencing recruitment difficulties, then needed to actively advocate for its own interests and how this resulted in the creation of the Atomic Weapons Research Establishment (AWRE). In 1947, Britain's initial nuclear weapons organisation, the High Explosive Research (HER) project, undertook development of a nuclear test device. HER was initially organised as a subdivision of the Armament Research Department (ARD), an institution primarily tasked with conventional weapons research and part of the Ministry of Supply (MoS).[1] Being a MoS project, HER was an entirely government led initiative where the staff and scientists involved were civil servants. After a tumultuous initiation, the HER project was able to test a nuclear device by October 1952. The delivery of this capability in five years has been subsequently praised by authors, such as Hymans, as being efficient, whereas contemporaries, such as Lord Cherwell, castigated the perceived organisational failures behind the project.[2] The contemporary perception of mishandling of the project led to the creation of the United Kingdom Atomic Energy Authority (UKAEA) and AWRE as a result.

By critically analysing a range of primary and secondary sources, this chapter will examine the challenges confronted by the HER project between 1947 and 1952. First, both international and economic conditions under which Britain's nuclear programme was undertaken will be presented. In brief, Britain's nuclear weapons programme operated under significant economic restraints, reflecting the reality of the UK's post WW2 need for civil and economic reconstruction. Additionally, the desire to resume nuclear cooperation with America provided much of the impetus for the programme until 1958 and this was reflected in many of the decisions surrounding HER. Using this context, the impact of subsequent policy decisions affecting the organisation of the HER project will be traced, to ascertain the underlying dynamics behind how the HER project was handled. This process will find, based on evidence and accounts from contemporaries, that while HER was managed efficiently, the interface between ministries and government on the one hand and the scientific and technical administration of HER was fundamentally undermined by a pervasive layer of

[1] The ARD was later renamed Armament Research Establishment (ARE) in 1948
[2] Hymans, (2012), p.33-34 & Lord Cherwell, HL Deb 05 July 1951 vol. 172 cc670-9

secrecy. Due to the level of secrecy imposed upon the project, HER suffered from unclear direction, struggled to maintain industrial priority and was constantly competing for staff with other research establishments. Critically, Penney and Portal, amongst others, played a vital role in fighting for HER's interests. Nevertheless, institutional infighting for resources led to frustrations with the MoS being readily evident from 1950-1951. However, many of the problems encountered appear to have been gradually overcome by reform and several staff retention schemes were implemented by HER. As a result, by the time the Hurricane tests had been conducted and further organisational reforms were being considered in 1953, many of the highlighted issues had already been resolved.

In terms of explicit knowledge, it is worth emphasising that much of the theoretical basis for implosion type weapons was already known to the British due to their involvement in the Manhattan Project. A detailed technical "Manual on design of Bikini bombs" (which remains classified) was produced by JL Tuck in 1946 from knowledge gained in America during the war.[3] However, essential elements such as knowledge over the metallurgy of fissile metals, the workings of polonium initiators and detailed production information of components remained as outstanding issues.[4]

Resolving these outstanding technical problems would require an indigenous effort as few Los Alamos "Alumni" worked directly for HER. A key exception was William 'Bill' Penney, the appointed superintendent for HER, who had also worked in the Manhattan Project.[5] Aylen states that as a result of his experience, "Penney had both the formal knowledge and the tacit know-how to transfer the essentials of bomb production to his new team."[6] HER's over reliance on Penney as both chief scientist and administrator (as Chief Superintendent Armament Research – CSAR) led to the somewhat sarcastic observation that, by the end of the project, the organisation at Aldermaston was "'5000 people helping Bill Penney.'"[7] However, it should be noted that despite the knowledge transferred, the British design used for the Hurricane tests and subsequently in Blue Danube devices was not a direct copy of an American design, instead incorporating additional safety features and a greater explosive efficiency.[8] The technical accomplishments necessary to deliver these capabilities were largely gained through intensive experimentation between 1950 and 1952. This is unsurprising as information on weapons had only been shared with British scientists on a 'need to know' basis.[9]

[3] Nuclear Weapon Archive, (n.d.)
[4] Goldberg, (1964), p.415
[5] Farmelo, (2014), p.369
[6] Aylen, (2015), p.33
[7] Makins, (1994), p.288, see also TNA, ES1/83, CSHER to Mr. Wilkinson, 25/08/1952 for Penney recognising his own indispensability.
[8] Cathcart, (1994), 317.4-320/673 & Gowing, (2) (1974), p.473-4
[9] Goldberg, (1964), p.414

The ability to marshal the staff and facilities needed for these achievements is instead presented as the culmination of a greater logistical and political process which is accounted for here.

Before turning to the analysis, a note on the limitations on the available sources should be made. The National Archives has multiple files concerning HER, but many have significant redactions based on national security concerns. Fortunately, most of these redactions appear to cover detailed technical matters which are not of specific interest for this study. When Penney's team faced prominent scientific or engineering challenges, they were brought up in a generalised way to the Atomic Energy Council (AEC) and a sense of the barriers conveyed to fellow councillors.[10] As will be suggested in the following analysis, overcoming technical challenges appeared to be a function of marshalling staff, time and resources. Another one of the limitations of the primary source material is that many of the papers are from HER's 'perspective' and often highlight problems rather than resolutions. As Cathcart states, "Penney was never averse to raising the alarm over dangers to his timetable."[11] Therefore, secondary literature, particularly Gowing's official history 'Independence and Deterrence' and Cathcart's 'Test of Greatness' are used, both of which employ evidence no longer accessible such as interviews with direct participants.[12] By combining new analysis of primary material and multiple secondary sources, this chapter presents a new perspective on the management of Britain's initial nuclear weapons efforts.

Context

Economic

Unlike the Manhattan Project conducted under war time conditions or the Soviet Union's rapid and determined attempt to obtain a measure of nuclear parity, Britain's effort was conducted with limited resources. Comparing the British effort to the Manhattan Project, the capital spent on fissile material production by "the Americans…[was] seventeen to twenty-five times the amount in half the time."[13] Given the weak economic situation of Britain following the war, combined with extreme pressures to reinvigorate the economy, build new housing, support social welfare programmes and a myriad of international commitments (Greece, Palestine, India, etc.), resources

[10] Minutes of which appear in National Archives files ES1/345-358
[11] Cathcart, (1994), 277.5/673
[12] Cathcart, (1994), Gowing, (1) (1974), & Gowing, (2) (1974),
[13] Gowing, (2) (1974), p.343

devoted to the atomic energy programme (AEP) were unlikely to be lavish.[14] While the AEP theoretically enjoyed high industrial priority throughout 1946-1952, even in terms of defence research spending, HER and the AEP had to compete with the ROTOR air defence project and developments in guided weapons.[15] Penney observed that this meant that "the Ministry of Supply and the country as a whole were trying to do everything at top priority."[16] In the end, the entire capital invested in AEP between 1946 -1953, equated to 0.67% of total government capital expenditure or 1.5% of total defence spending.[17] While Cathcart states that "at the time…[this] price seemed desperately high," both he and Gowing repeatedly credit the frugality and efficiency of both the AEP and HER.[18] As a result, Britain's proliferation programme represents the first case of nuclear proliferation by a non-superpower, being more akin to subsequent examples as resources and manpower were relatively limited.[19]

It was these limiting economic conditions that meant that "solely on the grounds of urgency," HER was placed within the MoS and the ARD to make use of existing spare capacity in relevant skills and facilities.[20] Rather than create an independent atomic weapons institution, this initial organisational structure was selected as "[the MoS] had…spare resources of land, factories and skilled manpower, and few questioned the Government's decision."[21] However, even at the earliest stages of development, it was debated whether a separate weapons institution should have been founded: a 21st July 1947 meeting between Penney and Portal stated that "the ideal arrangement may be for C.S.A.R. [Penney's leadership position] to concentrate all [nuclear weapons relevant] research within his organisation, [although] such a course may be impracticable."[22] This path was initially rejected as "manpower problems would have made the task impossible."[23] Nevertheless, this was a decision that likely benefited HER as "the core of Penney's team" was from the ARD, who were "well-versed in everything to do with the operation and testing of high explosives, including the measuring of phenomena of very short duration."[24] Although based on expediency, this foundation confirms the hypothesis that placing the HER project within ARD initially allowed for the prompt assembly of an embryonic nuclear establishment with experienced staff.

[14] Gowing, (1) (1974), p.4-5, the AEP contains all civil and military aspects of Britain's atomic efforts.
[15] Ibid., p.224
[16] Gowing, (2) (1974), p.498
[17] Ibid., p.37
[18] Gowing, (2) (1974), p.499 & Cathcart, (1994), 606.7/673
[19] Gowing, (2) (1974), p.350 & p.56-57
[20] TNA, ES1/346, AEC Minutes, 17/02/1949
[21] Birkenhead, (1961), p.298 & Cathcart, (1994), 47.9/673
[22] TNA, ES1/7, C.P.A.E. Conference, 21/07/1947
[23] Gowing, (2) (1974), p.445
[24] Ibid., p.22

American Assistance

The hope of resuming equitable cooperation on atomic matters between Britain and America was the other driving factor behind the scale of the UK's AEP. Britain had commenced its early nuclear weapons work with the MAUD committee and the Tube alloys programme from June 1940 onwards, with the 1943 Quebec agreement seeing the effort merged into the American Manhattan project for the duration of the war. Churchill had expected joint nuclear weapons cooperation to continue after the end of the war, but Roosevelt's death in 1945 and his failure to inform his colleagues of any accord aborted this initiative before it began.[25] Despite a November 1945 tripartite agreement promising nuclear energy cooperation between the UK, Canada and the US, the arrest of Alan Nunn May in March 1946 highlighted security concerns in the British nuclear establishment. In April 1946, a UK request for technical information on reactor construction was rebuffed by the Americans on these grounds.[26] This approach was officially codified in the 1946 McMahon Act which prohibited the transmission of atomic relevant 'restricted data,' even to US allies. This meant that if the UK wanted to develop either a civil or military nuclear programme, it would have to develop the technology itself. Other than knowledge gained through the UK's initial participation in the Manhattan Project, Gowing states that "in general there was little exchange of information and no exchange of materials other than uranium" during the period 1947-1952.[27]

While a full account of the subsequent negotiations between the US and UK is beyond the scope of this chapter, they did impinge upon the British weapons programme.[28] From the outset, the scale of the AEP and HER programmes were in part calibrated to prove to America that Britain possessed technical capabilities worthy of ongoing partnership.[29] As the HER project was therefore in part an element in a wider negotiation, its organisation was influenced by this approach. Although this will be evidenced when relevant in the following analysis, HER was kept secret in part to obfuscate its true progress and HER's split from the Armament Research Establishment (ARE) in 1950 was prompted by the potential for a possible merging with American efforts. [30]

[25] Atomic Archive, (n.d.)
[26] Cathcart, (1994), 55.6/673
[27] Gowing, (2) (1974), p.500
[28] These negotiations are comprehensively covered by Paul's "Nuclear Rivals: Anglo-American Atomic Relations, 1941-1952. Paul, (2000), p.5
[29] Paul, (2000), p.6 & Gowing, (2) (1974), p.500
[30] Gowing, (1) (1974), p.211

Hampered by Secrecy

As argued in the initial chapters of this thesis and demonstrated by Ouagrham-Gormley, secrecy can prove a debilitating barrier to proliferation as it blocks the transmission of tacit knowledge.[31] While the British nuclear weapons programme was conducted during a period in which there was no major taboo against nuclear weapons proliferation, Attlee imposed a level of secrecy on the project that was "beyond rational explanation."[32] This approach may have been a continuation of the Churchill government's war time mentality where information on atomic matters was kept to the "smallest possible circle."[33] While the British programme did not stop scientists within the programme exchanging knowledge within their own institutions, the level of secrecy imposed was frequently cited as having a significant negative effect on progress. Few cabinet ministers and civil servants were aware of the project, and as will be made clear, this had multiple significant debilitating effects on HER. Gowing clearly outlines that "the price of excessive secrecy… was confusion in some quarters and ignorance in others which reduced efficiency and involvement….had it not been for the extraordinary competence of…[leaders of the civil elements of the AEP] and William Penney, the project might have been an expensive fiasco."[34] The negative effects of this imposed secrecy were further exacerbated as they were imposed on a bureaucracy which, Baylis and Stoddart claim, itself emerged from a lack of clear decision making over nuclear weapons from 1945-1947.[35] The following section will confirm the hypothesis that secrecy impacted HER's attempts to maintain industrial priority, thus delaying the foundation of an initial skills base by limiting recruitment. It will also suggest that this generated discontent over HER's inclusion in the civil service, leading to the creation of the UKAEA.

When the GEN 163 sub-cabinet committee on nuclear weapons met for the only time in January 1947, the attendees decided that the British nuclear weapons programme would be conducted under "special arrangements conducive to the utmost secrecy."[36] Rather than solely attempting to prevent the Soviets uncovering technical details of the programme, other domestic and international considerations appear to have been equally pressing. Firstly, the high cost of the project would make it unpopular in the post-war environment with the public and certain Labour

[31] Ouagrham-Gormley, (2012)
[32] Gowing, (2) (1974), p.117
[33] Gowing, (1) (1974), p.5
[34] Ibid., p.57
[35] Baylis and Stoddart, (2015), p.33-36
[36] TNA, CAB130/16, GEN.163/1st Meeting, 8/1/1947

MPs.[37] Attlee would later divulge that he did not brief his full cabinet as he "thought that some of them were not fit to be trusted with secrets of this kind."[38] Other projects, such as the National Health Service had far more popular support in 1947, a year so economically fraught it was referred to as the Labour government's 'annus horrendous.'[39] If the scale of the intended project was more widely known, this increased the chances of a leak to the public, which would have placed further political pressure on an already unstable government.

In terms of the international dimension, Lord Portal who had been appointed in January 1946 as Director of the Atomic Energy Research Establishment, acted as a "powerful steer."[40] He advised keeping the programme secret, in order to not endanger the ongoing negotiations with the Americans over civil and military nuclear cooperation.[41] Another factor contributing to the imposition of the secrecy over the project was likely the desire to avoid accusations of hypocrisy in foreign affairs: Attlee had publicly championed an effort since August 1945 for international control over nuclear weapons.[42] Although this initiative failed, to reveal that Britain was preparing to proliferate while supporting international control over nuclear weapons would have immediately collapsed the initiative and invited scorn. Alternatively, Gowing suggests that the simple "awe and fear" inspired by the two recent demonstrations of nuclear weapons may have been sufficient to inspire the imposition of "very special secrecy" upon the programme.[43] In all likelihood, a combination of the above factors influenced the limited number of individuals informed of the project. Gowing reports that upon reviewing the imposition of secrecy arrangements in 1948, Bevin believed that it had been necessary for "political reasons and… [wanting to avoid] difficulties… with the United States."[44] In contrast, not all of those informed thought that such secrecy was necessary. The Chancellor of the Exchequer believed that "there was little point in trying to keep the fact secret" as it would be "widely assumed" that the UK would be proliferating anyway.[45]

As became evident, the plan that was approved by the GEN 163 committee to produce nuclear weapons had not been properly developed and scrutinised, likely due to its highly limited circulation. Lord Portal had commissioned Penney in October 1946 to produce a report in how to subvert the ARD in order to produce atomic weapons under the cover of "Basic High Explosive

[37] Paul, (2000), p.112
[38] Hennessy, (2007), p.69
[39] Bush, (2015) & Paul, (2000), p.11
[40] Hennessy, (2007), p.69
[41] Gowing, (1) (1974), p.182 & Baylis and Stoddart, (2015), p.31
[42] Gowing, (1) (1974), p.65
[43] Ibid., p.56
[44] Ibid., p.211
[45] Ibid., p.211

Research". [46] However, as this plan had been drafted in isolation, there had been no consultation with the Chiefs of Staff, MoD, MoS or the rest of the AEP. This meant that basic questions over the size of the desired nuclear force, division of tasks and clear lines of authority were left unaddressed. Penney himself wasn't even appraised of vitally relevant secret information; he was given "no bomb production assignment to match…[or the] plutonium production plan."[47] As the GEN 163 never reconvened and both the cabinet and Parliament were practically excluded from the atomic programme, there was little high level oversight. Answers to these issues had to be resolved in an ad-hoc fashion as the issues presented themselves.[48] This was the crux of many of the problems that the HER project would later experience as "Penney's plan [of using the ARD] was deliberately minimal in conception" and would have to be scaled up at the unexpected cost of other programmes who vociferously defended their interests.[49]

Nevertheless, the overbearing secrecy surrounding HER, with it only existing as a clandestine subdivision of the ARD, quickly presented its own problems after the weapons programme was initiated in May 1947. Despite the urgency of the work, Gowing argues that "excessive secrecy was delaying progress…for officers…[who] could not be given an inkling of the real nature of the job they were asked to do."[50] Material and recruitment problems were left unresolved despite the priority allocated to them, for as Hinton remarked, "priority so secret isn't terribly effective."[51] Secrecy also isolated HER from the rest of the AEP. For instance, Penney could only meet clandestinely with other former British Los Alamos staff.[52] While an 'informal agreement' existed between the Atomic Energy Research Establishment at Harwell and HER about research sharing, wider technical collaboration was impossible for as long as these conditions prevailed.[53] High level coordination was prevented as there was no representation for HER at the AEC.[54] This was especially important as the AEC was the premier committee for organising the AEP.[55] No representation led to basic confusions over the division of labour between the atomic establishments: both Penney and Hinton believed each other's organisations would be responsible for fabricating plutonium components.[56] Secrecy also imposed a logistical cost as "until 1949, all Penney's atomic contracts had to [clandestinely] go

[46] Cathcart, (1994), 47.9/673 & 63.2/673
[47] Gowing, (2) (1974), p.442
[48] Gowing, (1) (1974), p.51
[49] Cathcart, (1994), 134/673
[50] Gowing, (1) (1974), p.210
[51] Cathcart, (1994), 198.5/673
[52] Gowing, (2) (1974), p.445
[53] Ibid., p.445
[54] Cathcart, (1994), 206.1/673
[55] TNA, ES1/427, Report of the Committee on the Future Organisation of the Atomic Energy Project, 23/07/1953
[56] Cathcart, (1994), 193.3-195.9/673

through Harwell" which proved extremely inefficient for both organisations.[57] This was becoming increasingly unmanageable as by 1949, HER's requirements were "equal to at least 60 per cent of Harwell's…[resulting in] wasteful re-labelling, re-vouchering and forwarding."[58] There was a concern that this would "overload" the procurement system and contribute to delays for HER.[59] As a result of these issues, the Minister of Supply in March 1948 "reported to his colleagues that this [secret] arrangement was becoming increasingly ineffective, an impediment to progress and a possible source of embarrassment or even danger."[60] The struggle to recruit staff under both strict secrecy requirements and from within the civil service were therefore believed to be limiting the nuclear programme. This was a crucial step in the process of Portal and Penney becoming increasingly active in working with Lord Cherwell, who in turn would advocate for the creation of the UKAEA.

'Public' announcement

To resolve organisational issues and to improve secrecy, the Minister of Supply moved to place a 'D-notice' on British nuclear weapons efforts. A 'D-notice' was an informal but generally respected block on press coverage of particular topics, issued by the Parliamentary Press Committee. Issuing one was intended to provide leeway for modest disclosures over the intentions of HER to relevant officials, while enacting an opprobrium on wider press coverage beyond the simple protection of secrecy through obscurity. However, the Press Committee initially rejected the request, as it first stipulated some form of announcement to Parliament of the nuclear weapons project.[61] Therefore, on 12th May 1948, a Parliamentary question was raised for the Minister of Defence on whether "adequate progress" was being made on "the development of the most modern types of weapon."[62] The response stated that "all types of weapons, including atomic weapons, are being developed."[63] While the minister was asked to comment further on the development of atomic weapons, he refused to do so.[64]

[57] Gowing, (2) (1974), p.452
[58] Ibid., p.452
[59] TNA, ES1/346, AEC Minutes, 21/04/1949
[60] Gowing, (1) (1974), p.210
[61] Gowing, (2) (1974), p.136
[62] Gowing, (1) (1974), p.212
[63] Ibid., p.212
[64] Cathcart, (1994), 203.6/673

This "oblique" response satisfied the Press Committee who issued D-notice 25, blocking "the [further] disclosure of information about…the development and production of atomic weapons."[65] While the parliamentary question was reported, the D-notice deterred any wider comment and the public remained largely uninformed.[66] The immediate and crucial effect of this development was that Penney was invited onto the AEC and was henceforth able to coordinate the fabrication of bomb components with other constituent parts of the AEP, with Portal having official oversight over the entire endeavour for the first time through a single body.[67] This helped resolve outstanding issues, such as who would be responsible for uranium, plutonium and polonium components, each of which would require their own specialised facilities at Risely, Harwell or with HER (eventually at Aldermaston).[68] As construction of these facilities would take time, coordinating this process was vital to the eventual and timely outcome of HER.

Secrecy and Priority

While the imposition of a D-notice allowed for some prior limitations related to secrecy to be lifted, others remained in place. Secrecy continually impaired recruitment for HER as prospective candidates were not told the nature of the work they were applying for and had to wait weeks for their security statuses to be checked.[69] Nevertheless, the minor increase in openness in 1948 did allow for minor transfers within the civil service, filling secretarial and drafting roles which had previously been overly difficult to fill.[70] The other obstruction to HER progress related to secrecy frequently cited by Penney was an inability to cite the hard fought over atomic energy prioritisation to industry (the attainment of which will be dealt with in the following section). Penney himself stated in 1949 "[that] he did not benefit from a priority directive because he could not disclose that ARE was engaged on atomic energy work."[71] Nevertheless, Penney was complaining as late as February 1951 of steel shortages due to his inability to communicate his priority to industry.[72] While

[65] TNA, ES1/356, 'D' Notice No.25, 11/05/1948
[66] Cathcart, (1994), 203.6/673
[67] Cathcart, (1994), 206.7/673 & TNA, ES1/427, Report of the Committee on the Future Organisation of the Atomic Energy Project, 23/07/1953
[68] Gowing, (2) (1974), p.445-446
[69] Cathcart, (1994), 147.4/673 & TNA, ES1/356, AEC/221 – Draft Paper for Ministerial Committee on Atomic Energy, (n.d.)
[70] Cathcart, (1994), 198.5/673
[71] TNA, ES1/346, AEC Minutes, 17/02/1949
[72] TNA, ES1/348, AEC Minutes, 15/02/1951

Portal had stated in April 1949 that "secrecy would have to be relaxed rather than that H.E.R. work should be delayed," inefficiencies imposed by secrecy persisted.[73]

The apparent solution to these issues, championed by Portal from at least 1950 onwards, was that HER and Aldermaston "should be publicly announced… to be the Weapons Establishment."[74] This would have been beneficial as it would have allowed for a clear citation of priority to local authorities, industry and other ministries, thereby potentially expediting construction and HER work.[75] While this case had been made at the AEC as early as May 1949, the Minister of Supply only allowed building work at Aldermaston to be cited in relation to the general AEP.[76] However, priority citation was further hampered by the inability to connect HER (still operating from ARE facilities) to be linked to atomic work in any form.[77] If HER and Penney were connected to Aldermaston and Aldermaston was connected to atomic work, the press would quickly realise that atomic weapons work was underway at the site. Chapman Pincher appears to have made this connection in the summer of 1951, but "the Daily Express refrained from publication" as they did not want to "infringe the spirit…of the D-notice."[78] A new D-notice, '25b', was issued blocking publication of information linking ARE establishments to atomic work.[79] In the spring of 1951, the Minister for Supply realised the absurdity of the situation and concluded that "the official secrecy surrounding the U.K. atomic weapons project is unnecessary and futile and is a hindrance to progress."[80]

Although some were convinced of the benefits of greater openness, the Joint Intelligence Committees remained unmoved.[81] With HER activities now centralised onto the Aldermaston site, they believed in "keeping the Russians ignorant of the exact location of our Atomic Weapons Work."[82] However, some changes were implemented: Attlee's renewed priority directive for the atomic energy from September 1949 was reclassified from top secret to confidential in May 1951.[83] Until that point, prioritisation for HER had been "ineffective with industry because it could not be

[73] TNA, ES1/346, AEC Minutes, 17/02/1949
[74] TNA, ES1/356, AEC/221 – Draft Paper for Ministerial Committee on Atomic Energy, (n.d.)
[75] Ibid.,
[76] TNA, ES1/356, AEC/221 – Draft Paper for Ministerial Committee on Atomic Energy, (n.d.) & TNA, ES1/346, AEC Minutes, 05/05/1949
[77] TNA, ES1/356, AEC/221 – Draft Paper for Ministerial Committee on Atomic Energy, (n.d.)
[78] Gowing, (2) (1974), p.137
[79] Ibid., p.137
[80] TNA, ES1/356, AEC/221 – Draft Paper for Ministerial Committee on Atomic Energy, (n.d.)
[81] ES1/357(p4)
[82] TNA, ES1/357, AEC/251 – Atomic Energy Publicity, (n.d.)
[83] Gowing, (2) (1974), p.40

quoted."[84] While the AEC had wanted the new directive to be made entirely public, it did allow for HER to directly cite atomic energy prioritisation in select cases.[85]

The fact that such secrecy was maintained reflected the unique "'barbed wire' mentality" surrounding Britain's nuclear weapons efforts.[86] Secrecy related restrictions remained in place throughout much of 1951 and with elements proceeding into Churchill's term (such as Aldermaston's connection to weapons work), despite secrecy's negative consequences being brought to the attention of Ministers and routinely vented at the AEC. Although Prime Minister Attlee had accredited great priority and resources to the atomic programme, including the nuclear weapons effort, "his intentions were frustrated by the paranoia he himself had engendered."[87] From a political perspective, stringent secrecy was also problematic. The predicted resistance from left-wing labour MPs may have been challenging but the apparent lack of progress under the Attlee government towards a nuclear weapon was becoming a vector of attack from the Conservatives in the run up to the 1951 election. This was especially true after Lord Cherwell's victory in the House of Lords in July 1951, which censured the government's lack of progress towards developing nuclear weapons. [88]

The importance of protecting all information relating to the organisation of the weapons programme was also becoming irrelevant in the face of increasing leaks: in July 1951, Cathcart notes that the New York Herald Tribune reported that Britain would conduct a nuclear weapons test in "Australia within a year."[89] In retrospect, given the depth of Soviet intelligence penetration into the British Nuclear programme via Fuchs and Alan Nunn May, it is questionable what advantage the Soviets would have gained from a clear British announcement of intent, given they had detonated their first device in 1949. Perhaps the most ironic example of Soviet espionage on the British nuclear weapons programme in this period is highlighted by Cathcart; he notes that Donald Maclean as a senior diplomat stationed in Washington and as an agent for the Soviet Union, first informed the Americans and likely the Russians of Britain's nuclear ambitions in March 1948, two months before Parliament had any indication of the project.[90]

Nevertheless, after the October 1951 election, the secrecy surrounding the nuclear weapons programme was maintained, with Churchill largely following on with the policies established by

[84] TNA, ES1/36, R.E. France to Dr. D. Taylor, 27/08/1951
[85] TNA, ES1/348, AEC Minutes, 03/05/1951 & TNA, ES1/357, AEC/251 – Atomic Energy Publicity, (n.d.)
[86] Gowing, (1) (1974), p.212
[87] Cathcart, (1994), 199.9/673
[88] Farmelo, (2014), p.371
[89] Cathcart, (1994), 369.4/673
[90] Ibid., 201/673

Attlee.[91] The veil was partially lifted when Churchill announced on 26th February 1952 to Parliament that a weapons test would be conducted "in the course of the present year."[92] Ironically, Churchill lamented that "there was no reason why Parliament in time of peace should not have been made fully aware" of the decision to develop nuclear weapons, which drew furious protestations from Attlee, who stated that "We [Attlee and Churchill] have carried on precisely the same policy on the advice of our experts and advisers with regard to the publicity of these atomic matters."[93]

Debates over Priority: Limited Resources

Gowing notes that while Prime Minister Attlee had initially emphasised the AEP's importance verbally to a select cabinet audience, in 1946 it enjoyed no "specific priority statement."[94] In February 1947, this was rectified when Attlee issued a directive to all relevant ministries that the AEP was to be regarded "as a matter of the highest urgency."[95] While this may have been theoretically useful in expediting acquisitions for the AEP, the document was marked as top secret and therefore not widely distributed. Gowing further notes that as the government issued an unclassified high priority directive in 1947 for "items which the winter fuel crisis had revealed as critical," it effectively relegated atomic energy to "*primus inter pares*" with other industrial concerns.[96] Although Penney's early efforts in the ARD were implicitly included in this directive, the additional layer of secrecy separating HER from the rest of the atomic establishment blocked its usage on HER's behalf. Removing this barrier had motivated the 'public' announcement of the programme in 1948. However, maintaining priority and getting explicit overriding priority for atomic weapons was a more involved process, combining secrecy, bureaucratic infighting and reflecting the 'reflexive' nature of Britain's decision to acquire nuclear weapons.[97]

As resources were not infinite, favouritism exhibited towards the AEP would inevitably come at the expense of other government led projects, particularly defence related projects under the MoS. Ideally, Attlee should have clearly specified, early on to his administration, the relative importance he placed in each of these projects. However, repeated subsequent government

[91] Ruane, (2016), p.383 & Cathcart, (1994), 387.3/673
[92] Winston Churchill, HC Deb 26 Feb 1952 vol. 496 cc963-6. Aldermaston's connection to HER was only announced in 1953 – TNA, ES1/427, Report of the Committee on the Future Organisation of the Atomic Energy Project, 23/07/1953
[93] Winston Churchill, HC Deb 26 Feb 1952 vol. 496 cc963-6
[94] Gowing, (2) (1974), p.39
[95] Ibid., p.39
[96] Ibid., p.39
[97] Gowing, (1) (1974), p.209

communications regarding relative prioritisation were insufficiently detailed and poorly communicated due to overbearing secrecy. The ambiguous nature of these communications, left to individual interpretation, meant that priority became a "confusing riddle."[98] For instance, the prime ministerial directive in February 1947 that prioritised the AEP did not necessarily place it above "other high priority programmes."[99]

As a result, problems related to priority continued throughout the next two years, as various ministries interpreted the directive as they saw fit. For instance, the Ministry of Health and the Ministry of Labour had decided against the wishes of the Ministry of Works (who were charged with the construction of atomic infrastructure) that housing for atomic workers did not share the same priority as atomic infrastructure itself.[100] According to Penney, construction delays of HER facilities at Foulness due to differing priority interpretations were potentially imposing 12 month delays as early as November 1947.[101] This contest heavily impacted progress at Harwell and Windscale too, thereby delaying the delivery of fissile and radioactive materials to HER. HER was also directly affected by problems with priority at Harwell as they were reliant on routing their atomic priority orders through them.[102] Recruitment of staff at both Harwell and for fissile material production was becoming increasingly problematic, with Hinton's lack of engineers rivalling HER's issues and also threatening to delay the project.[103]

1949: Rapid Expansion

As later investigations of HER and the AEP's organisation by the Waverley committee would uncover, "the atomic project had never been given an overall directive."[104] This was evident in how little thought had been given to what the desired outcome for the HER project was. Sir Henry Tizard, an influential advisor on multiple defence science committees, emerged as the main critic to this undirected approach even though he was outside of the AEP bureaucracy. Unlike Cherwell, Tizard had a poor relationship with Churchill and had thus largely remained bereft of classified information relating to nuclear weapons between 1945 and 1947, but was nevertheless in charge of the Defence

[98] Gowing, (2) (1974), p.43
[99] Ibid., p.39
[100] Ibid., p.40-41
[101] Cocroft and Newsome, (2009), p.12
[102] TNA, ES1/346, AEC Minutes, 21/04/1949
[103] Gowing, (2) (1974), p.41 & p.344-346
[104] TNA, ES1/427, Report of the Committee on the Future Organisation of the Atomic Energy Project, 23/07/1953

Policy Research Committee (DPRC).[105] Therefore, when making recommendations on the allocation of defence research spending, Tizard's committee could confidently forecast potential conventional requirements, but only allude to nuclear weapon matters.[106] Nevertheless, the committee was the first body to attempt to rationalise a nuclear weapon requirement within British defence policy planning. Without full knowledge of existing commitments made towards producing nuclear weapons, the committee's report in July 1947 attempted to make an estimate of the number of atomic weapons required for an independent nuclear deterrent. The committee placed the figure at 1000, which was well beyond the capacity of the atomic programme in terms of fissile material production alone as planned at the time, "by a factor of 24."[107]

The realisation that difficult defence prioritisations would have to be made was more fully realised following the Berlin blockade, as the likelihood of war with the Soviet Union appeared more imminent in 1948. While not accepting the prior 1000 figure, the Chiefs of Staff concluded that 200 British nuclear weapons were needed in the event of war.[108] This was a significant increase from the tokenistic amount required in the near crash plan envisaged by Penney previously in 1946 and would be impossible with the then approved means of fissile material production.[109] While Portal resisted the setting of this figure as it appeared unattainable, thereby undermining the justification for the programme, the target instead resulted in a justification for increasing fissile material production.[110] Meeting these figures would mean significant increases in capital, labour and material expenditure; a plan was forwarded to build an additional third reactor at Windscale and a uranium enrichment plant at Capenhurst.[111] Given the worsening security outlook, the decision to proceed with this enlarged fissile material production plan was made in February 1949, despite reservations over the growing amount of resources devoted to the AEP which would now come at the expense of other defence projects.[112]

Competing for Skills: Existential Threat

[105] Gowing, (1) (1974), p.163 & p.188
[106] Ibid., p.188
[107] Ibid., p.189
[108] Ibid., p.216
[109] Ibid., p.217
[110] Ibid., p.219-220
[111] With research and plans for a further enrichment facility to be developed. Ultimately, both this additional facility and the third Windscale pile would be cancelled. Simpson, (1986), p.68
[112] Cathcart, (1994), 216.3/673

The balance of resources allocated to the AEP compared to other vital research projects such as guided weapons, created further grounds for ministerial infighting. This was especially true as the decision to expand the AEP "had [initially] been taken by Ministers without full knowledge of their implications for other crucial defence programmes."[113] While the previous period can be characterised by reserved inter-ministerial debate over the interpretation of priority, the new directive and increased resourcing led to the nuclear programme's existence being openly challenged. It was from this point that Tizard emerged as the chief "protagonist" in a move to deprioritise and potentially end the British nuclear weapons programme, in favour of reallocating resources back to conventional projects.[114]

Tizard's opposition to a British nuclear weapons programme slowly emerged around the idea that if the Soviet Union was to be deterred, resources should be allocated in programmes where they would provide novel increases to Western military capabilities, rather than sub optimally replicate American nuclear efforts.[115] Allocating resources to guided weapons (anti-aircraft missiles) and the ROTOR project (early warning air defence radar network) would also make sense if American deterrence failed and nuclear attack was imminent.[116] However, Tizard lacked direct influence: he chaired the DPRC, which advised on "the formulation of scientific policy in the defence field, [but] had no jurisdiction on the atomic project."[117] When partially inducted into the nuclear project through the foundation of the 'Atomic Energy (Defence Research) Committee,' which Tizard chaired from February 1947, he quickly found that their only responsibility was to denude other defence projects of their scientific staff for HER.[118] From this vantage, he would have seen the opportunity cost being expended by pursuing atomic weapons as it stripped scientists from other priority programmes and therefore Cathcart states that Tizard's "experiences on the cake-cutting committee… undoubtedly shaped…his views" against the nuclear weapons programme. [119]

Following a letter from Attlee confirming Portal's right to strip scientists away from other defence programmes due to atomic energy's overriding priority in February 1949, Tizard wanted to make it clear that this would jeopardise progress in other defence research areas.[120] Tizard therefore set about agitating the Minister of Defence and Chiefs of Staff through the DPRC to consider

[113] Gowing, (1) (1974), p.225-226
[114] Ibid., p.224
[115] Ibid., p.229-230
[116] Twigge and Scott, (2000), p.270
[117] Gowing, (1) (1974), p.225
[118] Gowing, (1) (1974), p.225 & Cathcart, (1994), 147.4/673
[119] Cathcart, (1994), 272.4/673
[120] Gowing, (1) (1974), p.224

whether the unbridled priority for the AEP should be retained.[121] The DPRC wrote a memorandum to the MoD, highlighting that the priority for the AEP would lead to the situation where the atomic bomb would be delivered before the means to deliver it, as well as generate delay research into other vital research areas.[122]

Tizard also personally met Lord Tedder, Chief of the Air Staff and convinced him of the need to review defence research allocation, at least on the grounds of "[preserving] some balance between the weapon itself and the means of using it." [123] This precipitated a meeting in May 1949 between "the Prime Minister, the Minister of Defence…the Minister of Supply…and Tizard" wherein he attempted to convince them of the need to reassess prioritisation.[124] The matter was referred back to the Chiefs of Staff who ultimately endorsed the priority awarded to the AEP and HER "for [the] political and strategic reason" of having an independent deterrent capability.[125]

The outcome of this review resulted in Attlee issuing another priority directive in September 1949, in an attempt to provide further clarification. While the statement that he "regarded… [fissile material production and civil nuclear research] as being in a class by themselves" may have appeared encouraging to the nuclear weapons effort, Attlee equivocated when affording HER the same definitive overriding priority.[126] Instead, HER was given the same priority as "other vital defence research and development projects."[127] Although Attlee foresaw some further conflict between HER and other defence projects over "some skilled scientists, engineers and technicians," he appears to have underestimated both HER's "insatiable... appetite for scientists" and the resentment this would engender from other research projects.[128] Within the context of rifts beginning to emerge around the potential partition between the conventional and nuclear weapons work within the ARE, large staff transfer requests submitted to Tizard inevitably created the pretext for further conflict.[129]

Even though Cathcart asserts that Tizard's efforts in 1949 to overturn atomic prioritisation were ultimately "doomed" due to their timing, Tizard did not abandon his effort to overturn AEP priority.[130] Ironically, as Tizard's arguments were based on pragmatic resource allocation amongst

[121] Gowing, (1) (1974), p.225-6 & Cathcart, (1994), 218.9/673
[122] Gowing, (1) (1974), p.P226
[123] Cathcart, (1994), 216.3/673
[124] Gowing, (1) (1974), p.226
[125] Ibid., p.227
[126] Gowing, (2) (1974), p.41
[127] Ibid., p.41
[128] Cathcart, (1994), 216.3-218.9/673
[129] Ibid., 218.9/673
[130] Ibid., 220.1/673

the Western Allies, as the prospect for imminent global war increased, the argument for prioritising atomic infrastructure and nuclear weapons decreased.[131] Almost immediately after the Chiefs of Staff's review in 1949, world events unfolded in such a way to support his thesis. The Soviet atomic bomb test in August 1949 nearly forced an immediate review of the atomic programme as it appeared the Soviets would produce significant quantities of atomic weaponry far faster than expected.[132] Klaus Fuchs' confession to atomic espionage in January 1950 (followed by the Burgess and Maclean affair in 1951) further eroded at the rationale for the British nuclear programme; resuming cooperation with the Americans seemed ever more distant given Alan Nunn May's actions had provided the impetus for the 1946 McMahon act.[133]

With Tizard once again agitating and Attlee refusing to directly intervene, the matter was passed on to the Chiefs of Staff.[134] They met in early 1950 to once again review the priority and necessity of the British nuclear programme, but this time, with a "new note of hostility."[135] The potential for transferring staff away from atomic work was openly considered, with Portal suggesting that this "would endanger the survival of the project."[136] According to Gowing, rather than arguing the merits of the AEP, Portal had to argue that cancelling the British Atomic weapons programme would not save a significant amount of capital as it had already been spent on construction. [137] Furthermore, any relieved scientists would likely be recruited by the United States rather than be useful in other conventional weapons research.[138] Additionally, Portal suggested weakening the programme would diminish the future prospects of Anglo-American nuclear cooperation as Britain would have little to offer.[139] Portal even threatened the possibility of his resignation, stating that if there were a downgrade in priority, "there would be no reason for him to continue in his appointment."[140] Due to this spirited if somewhat desperate defence, Portal was successful in maintaining the overriding priority enjoyed by the atomic project in a new directive issued April 1950, but this time the AEP was afforded the same joint overriding priority as guided weapons.[141]

[131] Gowing, (1) (1974), p.231-231
[132] Gowing, (1) (1974), p.228 & Cathcart, (1994), 272.4/673
[133] Gowing, (1) (1974), p.228 & Paul, (2000), p.5
[134] Cathcart, (1994), 218.9/673
[135] Ibid., 284.2/673
[136] Gowing, (1) (1974), p.233 & Cathcart, (1994), 280.5/673
[137] Gowing, (1) (1974), p.231
[138] Ibid., p.231
[139] Cathcart, (1994), 275.0/673
[140] Ibid., 275.0/673
[141] Gowing, (1) (1974), p.233

While Gowing states that Portal would ultimately "win" these confrontations, he had to continue to defend HER and the AEP's priority as it was "constantly disputed."[142] The last significant attempt to redress the prioritisation balance back towards conventional armaments during Attlee's administration appears to have been in February 1951, where Portal had to cite the programmes overriding priority to fend off a move to have the programme "slowed down."[143] In the same month at the AEC, committee members clearly demonstrated an awareness of the ongoing political sensitivity of prioritisation.[144] All divisions of the atomic programme were asked "to be discriminating in their use of priority…[for fear of] being attacked on the ground of misuse."[145]

Churchill surprisingly made a final effort to withhold resources from HER after the Conservatives came to power in late 1951. Churchill was shocked by the extent of the previous administration's efforts to acquire nuclear weapons and that the costs had been kept secret from Parliament. When Lord Cherwell pressed Churchill to approve a nuclear test for 1952, he unexpectedly refused, believing that American cooperation on nuclear weapons would be forthcoming.[146] Only after several weeks of pressure exerted by Lord Cherwell on Churchill and the realisation that £100 million had been spent on the project did Churchill assent for a test in 1952.[147] Additionally, due to the level of secrecy imposed on the project "all the old confusions were repeated" about priority and the AEP.[148] Penney complained in November 1951 that if "the top-priority in the UK atomic energy project is now the making of atomic weapons, then they [the government] should say so openly with clear voice."[149] Super priority status afforded to rearmament programmes was initially not given to the AEP until Churchill verbally reaffirmed the projects "absolute" priority. Even then, citations of super priority status in were allowed in mid-1952, only after the public announcement of the upcoming Hurricane tests.[150]

The Personal and Political

[142] Ibid., p.224 & p.233
[143] Ibid., p.233
[144] TNA, ES1/348, AEC Minutes, 15/02/1951
[145] Ibid.,
[146] Farmelo, (2014), p.381
[147] Ibid., p.382-3
[148] Gowing, (2) (1974), p.42
[149] TNA, ES1/329, Objectives of the U.K. Atomic Energy Project by C.S.H.E.R., 03/12/51
[150] Gowing, (2) (1974), p.42-43

Before assessing the direct impact that the contest over prioritisation had on HER, it is worth highlighting the role that individuals with strong convictions and personalities had on the gradual formation and retention of British nuclear policy from 1946-1952. Without a clear unified directive for what sort of nuclear force was necessary, and with the prospective chance of American assistance and/or war with the Soviets being imminent, the course of the programme appears to have repeatedly hinged on the input of individuals at key meetings. This perhaps reflects that the British decision to proliferate appears to have been made on emotional grounds to retain great power status, rather than on a rational defence basis.[151] The most famous of these interjections was made by Foreign Sectary Ernest Bevin in the GEN 75 meeting on October 1946, when, in reference to the nuclear bomb, he declared that despite the costs: "we've got to have this thing over here whatever it costs… We've got to have a bloody Union Jack on top of it."[152] Afterwards, Portal reportedly said to the Minister of Supply that "if Bevin hadn't come in then, we wouldn't have had the bomb."[153]

Beyond Prime Ministerial views on atomic weaponry, other personalities played a significant role in shaping or confusing policy.Gowing and Arnold, these were private attempts to "muffle..[

Nonetheless, the main clash of personalities was between Portal and Tizard. On the one hand, Portal is credited by Gowing with having "fought throughout, almost in barricade style to protect the projects formal priority."[154] Additionally, they state that "it is doubtful that they would have justified the high priority they got, especially against the vehement advocacy of Tizard, if it had not been for Portal."[155] On the other hand, one of the key factors behind Tizard's favouritism towards conventional projects observed by contemporaries was that "they saw in this the remains of Tizard's extreme soreness at his exclusion from atomic energy affairs during the war."[156] As Tizard's biographical memoir for the Royal Society states: "The dichotomy between 'nuclear' and 'non-nuclear' aspects of defence led to much frustration of the latter because of the abnormal priority and secrecy given to the former."[157] This is a factor that has been observed by Baylis, who commented that "bureaucratic interest alone…does not provide a wholly comprehensive

[151] Hennessy, (2007), p.59
[152] Ibid., p.48
[153] Ibid., p.48
[154] Gowing, (2) (1974), p.43
[155] Gowing, (1) (1974), p.233
[156] Ibid., p.33
[157] Victor and Scott, (1961), p.340

explanation for these disputes…Personality traits also played their part…Tizard and Portal…[seem to have shared] a mutual dislike between the two men."[158]

The hypothesis that a lack of representation on research committees threatened HER's continuation was true to the extent that unclear communication and lack of a firm strategic rationale for the early British weapons programme ceded a large degree of volition to these competing agents. However, the fact that it was "Portal… [rather than Tizard] who had the Prime Minister's ear" was itself a product of the intense secrecy surrounding the nuclear programme, which ensured routine and direct correspondence between the two men.[159] The value of consistent political support would again be demonstrated in the coming split between HER and the ARE, which would provide a further justification for the creation of the UKAEA as an autonomous body that could advocate for the weapons programme.

Stoddart and Baylis recall how "personality clashes within the Chiefs of Staff Committee itself… made any coordination of policy virtually impossible."[160] When Bernard Montgomery was appointed Chief of the Imperial General Staff, he "was not interested…and hardly disguised his contempt for" the views forwarded by colleagues representing other service branches.[161] The guided weapons project, the perpetual threat to HER and the AEP's priority, enjoyed their own support from notable members of the Chiefs of Staff and the Minister of Defence Emanuel Shinwell, who "stood by his guided weapons" in his efforts to ensure that they enjoyed equal priority.[162] According to Farmelo, requisition orders submitted by HER were routinely obstructed by "blinkered and uncooperative civil servants."[163] According to and] diminish" the effect of prioritisation which was "disliked by some Ministers and departments."[164] Nevertheless, these efforts were in part overcome due to the continued advocacy on behalf of HER by influential supporters such as Bevin during Attlee's term (especially during the priority disputes in 1949-1951) and then Cherwell under Churchill.[165]

Prioritisation's Impact on HER: the ARE Split

Centralisation and Competition over Skilled Staff

[158] Baylis, (1995), p.98
[159] Cathcart, (1994), 147.4/673
[160] Baylis and Stoddart, (2003), p.36
[161] Ibid., p.36
[162] Cathcart, (1994), 278.6/673
[163] Farmelo, (2014), p.369
[164] Gowing, (2) (1974), p.43
[165] Gowing, (1) (1974), p.233 & TNA, ES1/36, Penney to Cherwell – Priorities for A.E. Prog. PM's Objectives, 06/12/1951

While Tizard and Portal fought over the relative prioritisation of the atomic programme, this debate was "mirrored" by a rift in the Ministry of Supply that had a demonstrable impact on the organisation of the HER project.[166] HER had existed as an "anomalous entity," within the Ministry of Supply's ARD since 1947 and its expanding manpower requirements had brought it into conflict with the conventional work of the ARD.[167] Penney had originally guessed that he would require a non-industrial staff of 220 for the nuclear weapons programme, but in 1948 he now estimated that he required 500.[168] Antipathy within the defence research establishment against HER slowly built as more scientists were transferred to the nuclear weapons programme to satisfy this demand; Penney believed that coordinators of conventional projects "looked on me as a highwayman, picking their staff and this and that."[169] As the scientists and staff were stripped from other conventional work, mostly internally within the ARD/ARE, this fed into the escalatory spiral of bureaucratic conflict over priority, involving the Ministry of Supply, Tizard, the Chiefs of Staff and eventually the Prime Minister.

As Gowing notes, the production requirements forwarded by the Chiefs of Staff in 1948 for 200 weapons necessarily required scaling up manufacturing facilities.[170] While the production of high explosive components (such as the lenses) could be left at Royal Ordinance Factories, other components could not easily be fabricated in sufficient quantities at satellite HER facilities at Woolwich and Windscale.[171] Centralising this effort would mean the creation of a site dedicated to the British nuclear weapons effort. While both contemporary arguments and knowledge management theory would advocate for this approach at the earliest opportunity (to reduce costs and increase knowledge transmission), Penney resisted this initiative for as long as possible.

Penney's justification came from his mandate to deliver a workable nuclear device as promptly as possible, rather than institutionalise Britain's ability to produce nuclear weapons.[172] He argued that relocation to a new site would constitute a significant opportunity cost in terms of time, further delaying the first test. Penney was instead in favour of expanding the HER facilities at ARD sites.[173] This was because he recognised that moving to a new site would begin the divorce of the HER project from the ARD. This would mean redistributing resources and staff (some of whom were

[166] Cathcart, (1994), 273.8/673
[167] Ibid., 185.7/673
[168] Ibid., 142.3/673
[169] Ibid., 142.3/673
[170] Gowing, (2) (1974), p.446
[171] TNA, ES1/346, AEC Minutes, 03/02/1949 & TNA, ES1/346, AEC Minutes, 17/02/1949
[172] Ibid., p.447: The legacy of this decision was that ancillary non-nuclear component manufacture for Blue Danube continued to be devolved for Britain's first-generation nuclear weapons. See Aylen, (2015), p.40
[173] TNA, ES1/352, Research and Production Establishment for Atomic Weapons – AEC135, (n.d.)

unwilling to relocate to Aldermaston) that had previously been split between conventional and nuclear work.[174] In addition, the physical separation would result in HER administratively splitting from the ARD, meaning some duplication of function for administration, further stretching meagre resources.[175]

Despite these objections, the Ministry of Supply selected Aldermaston after an extensive search. The notion of whether a relocation was necessary was heavily discussed over the course of the AEC meetings in February 1949, where most councillors agreed on the need for "a British 'Los Alamos.'"[176] Of interest was how it was also concluded that no ministerial approval was needed for the creation of a nuclear weapons establishment "since it was implicit in the general authority to make atomic bombs."[177] According to Cathcart, Penney believed that reform, if immediately implemented, would place an unmanageable administrative burden upon himself and create contests over manpower with the remainder of the ARE precisely when HER needed to focus on weapons work.[178] Penney already had "a hundred vacancies to fill in senior grades" and was already engaging in debate with Lockspeiser, the MoS's Chief Scientist, over the transfer of electronic engineers to the programme.[179] Penney also believed that the expertise needed for a first nuclear device was best found amongst those familiar with conventional explosives rather than within an institution primarily focused on nuclear physics, stating that he "[could not] in fact see an important and certain research function for the atomic establishment if implosion bombs alone are to be deployed."[180] The other pressing concern for centralising the production of atomic weapons work on a single site was that there was "by no means a negligible risk" that it would be vulnerable to soviet atomic attack before an arsenal of weapons could be delivered.[181] To avoid these problems, Penny was successfully able to temporarily ensure that "unified control of HER and ARE were accepted for the time being."[182]

Rather than a need to improve the management of the HER project, the final impetus for separating HER from the ARE was the failure to agree on Anglo-American nuclear cooperation in 1950. Negotiations had resumed favourably in 1949 and it appeared that an agreement wherein

[174] Gowing, (2) (1974), p.450-451 & Cathcart, (1994), 292.2/673
[175] Gowing, (2) (1974), p.446
[176] TNA, ES1/346, AEC Minutes, 17/02/1949
[177] Ibid.,
[178] Cathcart, (1994), 211.2-216.3/673
[179] Ibid., 211.2/673
[180] TNA, ES1/352, Research and Production Establishment for Atomic Weapons – AEC135, (n.d.)
[181] TNA, ES1/352, Research and Production Establishment for Atomic Weapons – AEC135, (n.d.) & TNA, ES1/352, A Proposal to Recondition and Extend Facilities in Woolwich Arsenal for the Production of Atomic Bomb Components – AEC127, (n.d.)
[182] Gowing, (2) (1974), p.449

Britain would scale back its nuclear programme, offer its scientists and supply more uranium to the Americans in return for a limited nuclear arsenal and technical cooperation was soon to be agreed.[183] If HER was to be largely relocated to America, it would have to be divested from ARE, so Portal tasked Penney with planning for this contingency. [184] In the event, talks of cooperation floundered in early 1950 due to the confessions of Klaus Fuchs resurrecting fears of systemic infiltration of the British programme by Soviet agents.[185] While this could have aborted the planned ARE/HER split, Portal ordered Penney to continue with the plan regardless. Portal was likely concerned with the long-term institutionalisation of Britain's nuclear weapons knowledge and skills, whereas Penney appears to have been predominantly concerned with the immediate task of delivering a single viable nuclear device and was "sceptical about the ability of this country, unaided by the U.S.A. to make any progress with super-bombs."[186] Nevertheless, HER was outgrowing its accommodations within the ARE; Cockcroft notes that "by the end of 1950… [HER] work at Fort Halstead…[required] 600 of the 997 posts allocated to HER."[187] The secrecy and security requirements to keep the work at Fort Halstead physically separate from conventional work research making the situation untenable.

As Penney had predicted, the split between HER and the ARD caused him to "[drift] into his most bruising political battle" as he had to settle with the new ARE CSAR and MoS officials over the settlement of what staff would go where.[188] While Penney and the other AEC members perceived the theoretical benefit of "[concentrating] nearly every aspect of H.E.R." on one site, the organisational transition immediately encountered problems.[189] Firstly, there was a delay of several months as Penney waited for the new ARD CSAR to be appointed. The reallocation of staff from ARD to HER or vice versa could only be negotiated with the new appointee, so no progress on the new organisational setup could progress until a candidate was selected. This directly impacted HER work as Penney was unsure of what positions would need to be recruited for during this period.[190] Cathcart relays how Penney reported to Portal that the "continued inability to make the necessary appointments to the new posts in HER is having a catastrophic effect on the work."[191] This was

[183] Cathcart, (1994), 254.6-257.1/673
[184] Ibid., 254.6-257.1/673
[185] TNA, ES1/655, Note by British Representatives on Meeting Held in the Atomic Energy Commission Washington D.C. 03/10/1951
[186] TNA, ES1/352, Research and Production Establishment for Atomic Weapons – AEC135, (n.d.)
[187] Cocroft, (2010), p.6
[188] Cathcart, (1994), 267.3/673
[189] TNA, ES1/352, Research and Production Establishment for Atomic Weapons – AEC135, (n.d.)
[190] Ibid.,
[191] Cathcart, (1994), 267.3/673

repeated in AEC meetings, where Penney claimed that delays were "having a most serious effect on H.E.R. progress" and the matter may have to be taken to the Prime Minister. [192]

When the new CSAR was appointed at the end of July 1950, this precipitated an inevitable "fierce tug of war" as Penney, Poole and their staffs debated over the allocation of scientists and assignments to be split between the ARE and HER.[193] In terms of workload, the main contest was over who would retain purview over where shaped charged research should be conducted. The technology had clear utility for both ARD and HER as it had relevance to implosion type nuclear devices and conventional anti-tank warheads. Several months of back and forth exchanges resulted in an unsatisfactory provisional compromise wherein each organisation would have an independent explosives research team, but due to the secrecy surrounding nuclear weapons, research would not be shared by HER to ARE. [194] It was acknowledged that this opened up the potential for duplication of some shaped charge research, an unsatisfactory solution given the prevailing budget restraints.[195] Demarcation of conventional explosives work was only finally resolved between Royal Ordinance Factories, the MoS and Aldermaston in 1952.[196] The other general contest was over the split in what staff would go where. Even before the new CSAR had been appointed, Harry Garner, the MoS's new chief scientist after Lockspeiser, advocated providing staff "far more generously in ARE's favour" than to HER.[197] Garner's demands included "eight senior scientists, as well as several junior men" whose contributions were crucial to advancing the nuclear weapons programme.[198] Among these senior scientists, whose transfer was considered, was W. Challens, whose lead on designing the firing circuits and other electronics was vital to the point that Penney warned that his loss would "be seriously prejudicing the actual function of the weapon."[199] When Poole was appointed as ARE CSAR, he further exacerbated this crisis by "adding another twenty names to the list, including an entire team of men engaged on full-time lens trials."[200]

As both Cathcart and Gowing observe, the fact that the assertiveness of the conventionally minded partisans in the MoS were in the ascendancy in early 1950 reflected the pressure Tizard was placing upon Portal over the priority enjoyed by the AEP.[201] Poole and Garner explicitly quoted the

[192] TNA, ES1/347, AEC Minutes, 15/06/1950
[193] Gowing, (2) (1974), p.451
[194] TNA, ES1/226, Note of a meeting held at Fort Halstead on 20/10/50 to discuss Division of Staff and Responsibilities between A.R.E. and H.E.R., 20/10/50
[195] Ibid.,
[196] Gowing, (2) (1974), p.452
[197] Cathcart, (1994), 267.3/673
[198] Ibid., 269.9/673
[199] Gowing, (2) (1974), p.451
[200] Cathcart, (1994), 269.9/673
[201] Cathcart, (1994), 269.9/673 & Gowing, (2) (1974), p.451

renewed equal priority enjoyed by guided weapons, believing that this entitled them to a greater share of senior scientific staff.[202] However, as Portal managed to prevent the downgrading of the priority of the atomic project, the ARE's manoeuvres to reclaim staff appeared to have faltered in the latter half of 1950. September 1950 saw the "final and… biggest demand" from the ARE for 30 scientists out of Penney's 300, in a situation when HER was already "forty scientists under strength."[203] However, this demand may have only been a maximalist negotiating position as Garner suggested that he would have readily accepted an allocation of 15 scientists.[204] In the end, arbitration by the Sir Rowlands, Permanent Secretary of the Ministry of Supply, decided that only five HER scientists were to be transferred back to ARE, none of whom were vital to HER's progress.[205]

This five-month long affair had distracted management away from scientific work, created considerable uncertainty and, from the perspective of producing a viable nuclear device as early as possible, had not been necessary as Penney had been arguing in 1949. While the potential future benefits of centralising atomic weapons work on a single site under a dedicated establishment were appealing, they continued to incur an immediate opportunity cost. Some long time ARE staff were unwilling to relocate away from their current locations where they had settled their families and the ARE continued to poach staff with promotion offers.[206] Cathcart notes that between 1948 and 1950, scientists were being recruited on average at a rate of seven a month, but by mid-1950, this reversed to losing on average three a month.[207] Given that HER never hit its full complement of scientists ("there were never fewer than thirty vacancies waiting to be filled"), this was far from ideal but neither did it prove disastrous.[208] For example, In AEC meetings, Penney complained about "desperately" needing 30 skilled industrials for work at Fort Halstead and how "recruitment of scientific staff was not proceeding satisfactorily" as late as May 1951.[209] Nevertheless, Penney had guided HER through this transition period and could henceforth direct operations at Aldermaston as its new 'Chief Superintendent High Explosive Research' (or CSHER).

Even beyond the split from the ARE and the main conflicts over the AEP's priority receding, some material and staff shortages continued to affect HER. However, experiencing problems approaching testing was especially critical as even as of March 1952, "only one of its seven principal

[202] Gowing, (2) (1974), p.451
[203] Cathcart, (1994), 277.5/673
[204] Ibid., 277.5/673
[205] Gowing, (2) (1974), p.451
[206] Cathcart, (1994), 280.1/673
[207] Ibid., 280.1/673
[208] Ibid., 280.1/673
[209] TNA, ES1/348, AEC Minutes, 17/05/1951

components was ready and in satisfactory condition."[210] Most of the preceding time between 1947 and 1951 had been spent researching, creating specifications and organising the construction of facilities needed for assembly of finished components. Only after the necessary radioactive and fissile materials were delivered could certain components such as the tamper, initiator and the core be finalised.[211] Even then, the facilities to handle plutonium at Aldermaston were completed just in time for these deliveries such that they "matched to an improbably exact degree."[212] This led to a "frantic race against time with serious problems solved only at the eleventh hour."[213]

The two main problems that still faced Penney were understaffing and being unable to effectively quote industrial priority to ensure that components were delivered on schedule. Understaffing meant that some of the workshops fabricating components for Hurricane were operating at "not more than 2/3rds capacity of their machines."[214] This led Penney to stress the immediate need for "up to 50 skilled industrials [or] we shall either fail to keep our dates, or the Trials [sic] will have to be carried out on a restricted basis."[215] As Gowing notes, while it is not recorded how this issue was resolved, the timetable of Hurricane was still met, so either they made do or more workers were diverted to HER.[216]

In terms of obtaining components from industrial suppliers, priority was still an ongoing issue. When confronted over problems acquiring electronic components for HER in potential competition with the ROTOR and guided weapons projects, the Ministry of Supply equivocated and called for an "appeal at [a] high level" to resolve these issues.[217] This reached an impasse in September 1951 with difficulties in obtaining necessary electronic components for contractors that was giving HER "ground[s] for disquiet".[218] Given the equality between atomic energy and guided weapons priority, Penney complained that "the best priority we can quote is that we are agents for atomic energy and this is not strong enough."[219] Penney asked for "a government statement…that such priority is the first priority in Defence and ranks higher than Export priority."[220] This was not forthcoming and the solution was only found with a hastily imposed redesign of the firing circuits, completed and tested in "only two months," incorporating components with looser tolerances that

[210] Cathcart, (1994), 374.5/673
[211] Ibid., 371.9/673
[212] Gowing, (2) (1974), p.348
[213] Ibid., p.472
[214] TNA, ES1/83, H.E.R.'s Need for Skilled Industrials, (n.d.)
[215] Ibid.,
[216] Gowing, (2) (1974), p.465
[217] 07TNA, ES1/36, A.S/At.En.(S) to D.R.P., 14/09/1951
[218] TNA, ES1/36, Penney to Cherwell – Priorities for A.E. Prog. PM's Objectives, 06/12/1951
[219] Ibid.,
[220] Ibid.,

were less in demand.[221] Overriding super industrial priority was only granted and distributed on 26th March 1952, only six months before the Hurricane test was conducted.[222] While the intention was to accelerate the programme "to the greatest possible extent," it is difficult not to see this as having come too late to have been of much practical benefit.[223] Nevertheless, the ability for HER to overcome these final hurdles before the test is instead credited by Cathcart in part to Penney being an "invincible optimist" and by Gowing to Penny's organisational abilities.[224]

Resolving Skill Shortages: Staff Recruitment and Retention

As observed, one of the main ongoing issues hindering HER was the ability to attract and retain staff. As Brooking (Penney's deputy since 1950) acknowledged, "a 10 million [pound] project without proper staff to operate it is no use to anybody."[225] While Gowing assessed the absolute number of staff required by the entire AEP to be "insignificant" at a national level, the manpower demands of the project were "high and at some points…critical" given the overall economic context.[226] Furthermore, the tight requirements to deliver within their specified timeframes did not allow for much training or ancillary research to be conducted while the programme was progressing.[227] Without the necessary complement of already experienced scientists, engineers, industrialists, draughtsmen, labourers and administrative support staff being both recruited and retained, the programme may have been unworkable or unsustainable. Even with the Hurricane tests nearing fruition, Penney worried about the fragile state of institutional knowledge in 1952 as "the HER establishment could easily become sterile in five to ten years unless we both keep the best of our top men and get an adequate supply of youngsters."[228]

However, as Penney's modest initial proposals for HER had to be subsequently scaled up, HER was "constantly jeopardised by critical staff shortages and problems" and recruitment was perpetual.[229] Transferring staff from other defence projects to HER (mostly within the ARD) was the

[221] Gowing, (2) (1974), p.465
[222] TNA, ES1/36, Penney to Cherwell – Priorities for A.E. Prog. PM's Objectives, 06/12/1951
[223] TNA, ES1/36, Super-Priority for Certain Defence Contracts, 06/12/1951
[224] Gowing, (2) (1974), p.474
[225] Gowing, (2) (1974), p.31 & TNA, ES1/36, Brooking to A.S/At.En.(S), 16/03/1951
[226] Gowing, (2) (1974), p.37-28
[227] TNA, ES1/353, Draft Memorandum from C.P.A.E. to the Chiefs of Staff, 08/1949 Pdf124
[228] TNA, ES1/83, CSHER to Mr. Wilkinson, 25/08/1952
[229] Gowing, (2) (1974), p.73

only way to come close to the prescribed numbers.[230] Therefore, clashes over the allocation of staff were the main basis for conflicts over priority within the civil service and HER. There was even competition within the atomic programme for staff: Cockcroft's (leader of the reactor element of the AEP) interpretation of priority favouring Harwell led to him offering "posts… to scientists who would have preferred to work on weapons."[231] Accordingly, overcoming staffing issues proved Penney's main challenge as administrator of HER. This was certainly perceived at the time as Cathcart notes that "Portal was anxious about Penney's mounting commitments: in January 1949 he had complained to the Chiefs of Staff that the chore of finding staff was diverting the CSAR from his real task of developing a weapon."[232] Even design decisions on the Hurricane test device reflected the manpower shortages and skill gaps as "a variety of expedients and some narrow shaves" were implemented to get it into a usable state.[233]

Penny's ability to overcome these challenges was hampered by several compounding factors. Most pressing was HER's perennial level of secrecy. Not only did secrecy hinder recruitment by making it impossible to disclose the nature of the work in placement advertising, but it also made the jobs unattractive for "the security of the work…[was] so restrictive."[234] Scientists were constrained in their research activities, unable to publish, the work was more time pressured and dangerous; employment within HER was unattractive compared to Harwell.[235] When suitable candidates did apply, attempts to rapidly integrate them into the HER workforce were additionally "frustrated by delays in security clearance."[236] Secondly, despite the nature of the work, pay was relatively derisory compared to private industry and fixed according to civil service pay scales.[237] Management in Aldermaston complained in 1951 that "we are finding the gravest difficulty in recruiting any personnel… and this is being aggravated by the low scale of wages."[238] When assessing the recruitment of mechanics, of those selected for interview "when the conditions of service are known i.e., rates of pay, no special housing facilities, it is anticipated that not more than say 5% would be possible starters."[239] As a result, Penney considered that one of the "major advantage[s of

[230] Ibid., p.73
[231] Hartcup and Alliborne, (1984), p.142
[232] Cathcart, (1994), 213.8/673
[233] Gowing, (2) (1974), p.74
[234] TNA, ES1/83, CSHER to Mr. Wilkinson, 25/08/1952
[235] Gowing, (2) (1974), p.72
[236] TNA, ES1/348, AEC Minutes, 17/05/1951
[237] Gowing, (2) (1974), p.39-40 & TNA, ES1/329, Future Organisation of the AERE, 16/11/1951
[238] TNA, ES1/83, "M" Rate – M.O.S. Establishment, Aldermaston, 25/01/1951
[239] TNA, ES1/83, Howe to Brooking, 31/03/1952

an Atomic Energy Corporation] would be…[the ability to] take the right man and pay him the right salary [which] would do more to ease this situation than anything else.[240]

Even the mechanism by which many of the staff were recruited through the Civil Service Commission was inefficient. The indirect, laborious process, described as "Chinese whispers" by Cathcart "was very often decisive in losing candidates who were able to pick and choose among employers."[241] Moreover, due to HER being within the civil service which operated a centralised promotion scheme, upwardly mobile staff could be promoted out of the project.[242] One absurd bureaucratic oversight highlighted in correspondence from Aldermaston in August 1951 was that young staff were being called up for national service. [243] This not only farcically undermined the secrecy of the project but also whisked away staff when they had just been recruited. Finally, the move to Aldermaston after the split from the ARE created uncertainty for the workforce: the physical relocation of staff, many of whom had families and were settled was a great inconvenience.[244] As a result, the speed of centralising the effort was decelerated; it was acknowledged that a degree of "remote control" would be necessary for HER's administration across secondary satellite facilities.[245]

Essential Bomb Components: Houses, Buses and Salaries

While Penney as the superintendent of HER had a limited ability to overcome the underlying challenges faced by his organisation (i.e. imposed secrecy, the split from ARE, competition for priority, etc.), he could appeal at the AEC, to Portal, Sir Fredrick Morgan (Portal's replacement after his retirement in Autumn in 1951) or Cherwell for greater resources. These lobbying efforts focused on several measures that were implemented over time to improve recruitment and retention of staff. As the lack of staff was highlighted by contemporaries as the key bottleneck of the programme, these seemingly innocuous measures likely had a major impact on delivering the Hurricane tests on time, judging by the attention devoted to these issues by HER administration and the AEC.[246]

[240] TNA, ES1/329, CE/HER to CS/HER – Proposed Atomic Energy Corporation, 23/11/1951
[241] Cathcart, (1994), 282.6/673
[242] Gowing, (2) (1974), p.74-75 & TNA, ES1/329, Re-organisation of Atomic Energy – E3, 11/12/51
[243] TNA, ES1/83, Brooking to Wilkinson, 29/08/1951 - Afterwards, deferment was granted in special cases, but complaints continued to be a problem into 1953. See TNA, ES1/341, Memorandum to C.E./A.W.R.E., 16/09/1953
[244] Gowing, (2) (1974), p.75
[245] TNA, ES1/237, The Interim Organisation of H.E.R. whilst Located at Fort Halstead, (n.d.)
[246] Gowing, (2) (1974), p.38

One of the main lures for new recruits to HER was the potential access to newly built housing, which was in desperately short supply after the war in Britain.[247] While only a "very few [scientists]…enjoyed the [free] provision of a house," accommodation with controlled rents was considered one of "the most potent inducements we can offer [to] labour."[248] As a result, providing housing for HER workers, from labourers to scientists at both Fort Halstead and Aldermaston proved "to be a major, almost obsessive, anxiety."[249] However, the construction of housing was often behind schedule as both the Ministry of Labour and Health refused to concede that atomic energy priority covered the provision of housing.[250] The 17th February 1947 AEC meeting agreed that while they felt the Prime Ministers declarations "placed an undue emphasis on secrecy," overturning this held equal weight to getting "a specific reference…be[ing] made to priority for housing."[251] Attlee's new directive following the expansion of the programme did cover housing, but this did not immediately solve the issue around Aldermaston, which was already "ill-provided with houses."[252] Although Gowing claims that "from 1950 housing ceased" to be a serious issue, complaints persist in administrative papers from Aldermaston; for instance, a paper in August 1951 notes that "the lack of sufficient housing…in the area is still a serious handicap to recruitment." [253] HER papers also make it clear that housing continued to make "it extremely difficult to recruit staff to Fort Halstead and subsequently transfer them to Aldermaston."[254] This is unsurprising given that accommodation for an estimated 600 families from ARE relocating to Berkshire had to be provisioned for.[255] While it appears that housing was never solved satisfactorily within the timeframe of the Hurricane tests, the pressure exerted by the HER administration appears to have sufficiently relieved the problem.

In addressing the pay of HER staff compared to industry and universities, there was only a limited amount that HER's administration could do, other than highlight the problem at AEC meetings. Overturning pay restraint was an uphill battle while HER and the rest of the AEP were part of the civil service as they were bound to civil service rates of pay, meaning "the authority to pay the market rate in salaries was denied."[256] Some special rates were available, but they were rarely offered and slowly implemented.[257] While Penney repeatedly bemoaned this fact, pay restraint

[247] Ibid., p.77
[248] TNA, ES1/237, Brief Note of a Meeting on 19th September 1950 to discuss administration of H.E.R., 19/09/1950 & TNA, ES1/352, Research and Production Establishment for Atomic Weapons – AEC135, (n.d.)
[249] Gowing, (2) (1974), p.77
[250] Ibid., p.40-41
[251] TNA, ES1/346, AEC Minutes, 17/02/1949
[252] Gowing, (2) (1974), p.76-77
[253] Ibid., p.77
[254] TNA, ES1/237, The Interim Organisation of H.E.R. whilst Located at Fort Halstead, (n.d.)
[255] TNA, ES1/273, Housing and Hotel Accommodation at Aldermaston, 22/10/49
[256] Gowing, (2) (1974), p.81
[257] Ibid., p.63

reflected Britain's contemporary economic situation. Devoting extra capital for HER salaries would have disenchanted all other civil servants, undermined national "income restraint [that] was essential to curb inflation."[258] However, as this problem was the result of macroeconomic conditions, it receded as conditions improved. Both the 1949 Chorley Report and the 1951 Gardiner Report recommended higher rates of pay for senior civil service grades.[259] Ensuring that the pledged pay increases were implemented became a further preoccupation as it was perceived that "the Chorley Report would go a long way towards solving the problem."[260] From mid-1950 onwards, a joint "Treasury-Ministry of Supply Committee worked satisfactorily…and most of the salary complaints disappeared."[261] Although pay increases were only gradually implemented, it meant that by the end of 1952 "dissatisfaction over salaries had generally narrowed" across the AEP.[262] A temporary labour shortage in the London area in 1951 affected Aldermaston, but self-corrected overtime.[263] Nevertheless, the inflexibility to determine salaries (especially for senior posts) heavily influenced arguments towards the foundation of the UKAEA.[264] While still only a proposition in August 1952, Penney moved to increase the number of superintendent posts at Aldermaston simply to provide some internal career progression within HER to improve retention.[265]

If pay could not be significantly improved, the main initiative beyond housing construction implemented to assist with recruitment and staff retention at Aldermaston was the creation of an 'Assisted Travel' scheme. Created in reference to Harwell's programme, where a fixed low rate bus scheme collected workers from the surrounding area and shuttled them between Aldermaston and Fort Halstead, this simple measure would have eased the burden on site transition and increased the catchment area for employees (thereby easing recruitment and lowering the demand for housing in the immediate areas).[266] Even though such a measure may initially appear trivial, in the face of "reluctance on the part of Headquarters to introduce an Assisted Travel Scheme at Aldermaston," Penney believed that it was an "essential requirement if present staff were to be retained and [for] future recruitment."[267] A MoS communique from Aldermaston (dated 25th January 1951) ranked

[258] Ibid., p.82
[259] Ibid., p.62-63
[260] TNA, ES1/353, Note of a meeting in the Permanent Secretary's Room, 27/09/1949
[261] Gowing, (1) (1974), p.423, & TNA, ES1/347, AEC Minutes, 03/08/1950
[262] Gowing, (2) (1974), p.83
[263] Ibid., p.64
[264] See: TNA, ES1/347, AEC Minutes, 20/04/1950, TNA, ES1/347, AEC Minutes, 03/08/1950, TNA, ES1/353, A Statement of Outstanding Difficulties in meeting the Required Programme for the production of Fissile Material and a Consideration of Various Methods for Removing Them, 04/07/1949, ES1/329, Re-organisation of Atomic Energy – E3, 11/12/51, ES1/329, Future Organisation of the AERE, 16/11/1951
[265] TNA, ES1/83, CSHER to Mr. Wilkinson, 25/08/1952
[266] TNA, ES1/347, AEC Minutes, 07/12/1950
[267] Ibid.,

assisted travel as more important than increasing salaries for attracting new personnel.[268] Rather than discussing problems in weapons design immediately, the first agenda item for HER superintendents held on the 5th February 1951 was discussing the implementation of assisted travel.[269] Although this was perhaps an "obvious necessity," the travel scheme's implementation from February 1951 helped ease the logistical burden of Aldermaston and helped to progress the HER project.[270] While perhaps not the most obvious aspect of a nuclear weapons programme, the attention paid to these social and logistical aspects by senior management indicates an awareness that their task was not only a technical task but a social one too.

Lord Cherwell: An 'Unsatisfactory' Nuclear Programme?

Despite the fact that Cherwell was employed by the Ministry of Supply "as a member of Lord Portal's Technical Committee," he would emerge from 1949 as one of the ministry's chief critics and the driving force behind the foundation of the UKAEA.[271] Cherwell's personal role in the foundation of the UKAEA is hardly in doubt: his official biography claims the UKAEA as his "personal triumph," which is credible, given his insistence on the issue despite the opposition of Attlee, Churchill and the MoS.[272] While Gowing writes that Cherwell "knew a great deal about the programme and its problems," it appears that his perceptions were largely influenced by Portal, who "briefed" him on the problems experienced by HER and the wider AEP.[273] Given Portal's role as Controller of Production (Atomic Energy), it appears that much of the negativity surrounding competition for resources and scientists within the MoS was transmitted to Cherwell, without the larger economic, political or defence related context.[274] Furthermore, as Farmelo states, Cherwell's criticism was "sometimes woefully ignorant of…[the AEP's actual] progress".[275] While there were certainly problems experienced by HER within the Ministry of Supply, this chapter has argued that many of them can be traced back to a combination of Attlee's decision to enforce strict secrecy upon HER and the related problem of unclear prioritisation while attempting to minimise the cost of the effort.

[268] TNA, ES1/83, "M" Rate – M.O.S. Establishment, Aldermaston, 25/01/1951
[269] TNA, ES1/11, Minutes of a Meeting of Superintendents held in CSHER's Room, 05/02/1951
[270] TNA, ES1/237, Brief Note of a Meeting on 19th September 1950 to discuss administration of H.E.R., 19/09/1950 & TNA, ES1/348, AEC Minutes, 15/02/1951
[271] Gowing, (1) (1974), p.32
[272] Birkenhead, (1961), p.295
[273] Gowing, (1) (1974), p.407, Birkenhead, (1961), p.270 & Farmelo, (2014), p.371
[274] Gowing, (1) (1974), p.45
[275] Farmelo, (2014), p.374

Cherwell's assertion in 1951 that "salaries…housing, transport and so on…could easily be dealt with in an independent corporation," compared to the civil service and within the same budget seemed optimistic given the lack of evidence behind the statement.[276]

Instead, Cherwell's opposition to the MoS was perhaps based more on emotional grounds, given that "dissatisfaction… did not begin until the autumn of 1949, when the first Russian atomic bomb was exploded."[277] In his Lords motion in 1951, he spoke of the "unsatisfactory" and "incredible" fact that the Soviet Union had acquired nuclear weapons first.[278] It is therefore worth observing that Cherwell's criticisms of the management of the AEP hinged on the failure to deliver nuclear weapons promptly, in comparison to the Soviets or the Americans. Furthermore, Cherwell reportedly also had a pre-existing ideological "dislike… [for the] principle of a Government Department running an industry."[279]

In terms of implementing his agenda, Cherwell's first move towards an atomic energy corporation began in 1950. Cherwell and several associates pressured the Labour government into reviewing the organisation of the AEP.[280] While the AEC viewed the proposal with cautious optimism as it may have allowed for greater flexibility in setting salaries, they were nervous of the disruption that its implementation may have brought.[281] However, the review rejected the idea of an independent atomic corporation, instead creating the joint Treasury-Ministry of Supply Committee which allowed for quick decisions on exceptional rates of pay.[282] Initial resistance to the move towards a corporation was further stirred by the Treasury, who wanted to maintain control of the finances, and the MoS who wanted to retain the AEP.[283]

Undeterred, Cherwell steered the Technical Committee to pass a resolution favouring the institution of an atomic energy corporation. This renewed pressure led to a sharp series of exchanges between Cherwell and Attlee, where Cherwell cited that the "over whelming majority of people who have really been concerned with the project" were strongly in favour of an independent corporation, whereas Attlee appealed for the need for "concrete evidence" to justify such a disruption.[284] Cherwell's letter to the Prime Minister even contained a perceived "implied threat" to

[276] Lord Cherwell, HL Deb 05 July 1951 vol. 172 cc670-9
[277] Farmelo, (2014), p.298
[278] Ibid., p.298
[279] Paget and Scott, (1958), p.66
[280] Gowing, (1) (1974), p.422
[281] TNA, ES1/347, AEC Minutes, 20/04/1950
[282] Birkenhead, (1961), p.299
[283] Ibid., p.299
[284] TNA, PREM8/1556, Lord Cherwell to Prime Minister, 06/03/1951 & Birkenhead, (1961), p.299

convince Penney to accept a professorship at Oxford, unless his reforms were implemented.[285] In Cherwell's letter to the Prime Minister dated 31st May 1951, Cherwell lamented that the organisation of the AEP was becoming a "party issue."[286] Birkenhead believes that at some point in the spring of 1951, he convinced the Conservative shadow cabinet to adopt his organisational reforms as their official policy.[287] This provided the prelude to Cherwell's July 1951 House of Lords motion where he, with the Conservative party's backing, admonished the government on their lack of progress towards delivering a nuclear bomb.[288]

Greater Autonomy: Towards the UKAEA

With the election in October 1951, the Conservatives were in power and Cherwell was appointed as Paymaster-General. Rather than finding strong support for reform from within the AEP, Cherwell was surprised to find concern from scientists over the creation of an independent atomic corporation.[289] Finding resistance from AER staff, the wider civil service and fellow cabinet ministers, Cherwell was forced to delay his plans until after the Hurricane tests.[290] Nevertheless, in April 1952 an interim organisational reform was made where an Atomic Energy Board replaced the AEC. It was still within the civil service and the AEP was still under the MoS, but the new board was chaired by Cherwell, who as a government minister could exert more influence that Portal or Fredrick Morgan.[291] Following the success of the Hurricane tests, Cherwell forcefully resumed his push for an independent atomic corporation. Cherwell went as far as to threaten to resign unless Churchill supported his policy.[292] This threat was ameliorated with the establishment of the Waverley Committee who were tasked with drafting a white paper on the proposal. Eventually, the white paper was published in November 1953, leading to the foundation of the UKAEA in July 1954.[293]

While the desired outcomes and impact of the foundation of the UKAEA on the AWRE will be considered in the next chapter, it is worth refuting Cherwell's assertion that "the present organisation [HER and the AEP under the MoS]— [was] the cause of most of our delays and

[285] TNA, PREM8/1556, Prime Minister to Lord Cherwell, 09/03/1951
[286] TNA, PREM8/1556, Lord Cherwell to Prime Minister, 31/05/1951
[287] Birkenhead, (1961), p.300
[288] Gowing, (1) (1974), p.424 & Lord Cherwell, HL Deb 05 July 1951 vol. 172 cc670-9
[289] Birkenhead, (1961), p.300
[290] Cathcart, (1994), 402.3/673
[291] Gowing, (1) (1974), p.428-9
[292] Ibid., p.434
[293] Paget and Scott, (1958), p.66

frustrations" in delivering nuclear weapons.[294] Even more bluntly, Cherwell asserted to Churchill in 1952 that "with a different organisation…[a nuclear test] would have been held two or three years earlier."[295] Despite Cherwell's repeated assertions, the only practicable ways in which the Hurricane test could have been brought substantially forward would have been to start earlier or devote even greater resources to the project. However, in both cases, these limitations were made on reasonable grounds. The "dragging effect" of the Initial delays were imposed to test the extent of the American's willingness to cooperate on atomic developments.[296] Furthermore, additional resources could only have done so much as recruiting manpower on all levels was the real challenge. For certain skillsets such as electronic engineering, this represented the limits of available skilled manpower in the country.[297] Although paying more across the AEP may have aided the project, it would have broken pay restraint across the civil service in a time of austerity. Although hypothetically there could be greater flexibility to pay different rates within an independent corporation, increases for certain roles and grades would come at the expense of others. As Gowing states, "the miracle in the project as a whole was that so much was done so quickly by so few men."[298] Cherwell's failure to acknowledge these factors suggests ignorance given that significantly faster production of fissile materials alone in this time frame would have been practically impossible.[299]

Being briefed by Portal and in touch with Penney, Cherwell was correct in his observations to the extent that HER's relationship with the MoS had at times been fractious. The MoS had other ongoing defence projects other than HER to devote staff and resources to and had at times mishandled recruitment on HER's behalf.[300] As traced in this chapter, these issues reflected the result of an incremental process where HER faced a high demand for skilled staff but struggled to recruit them from within the civil service. Secrecy combined with unclear communications from Attlee's government led to contests over the relative priority of the project. This had allowed room for civil servants to interpret government directives in line with their respective institutional interests. However, the civil service had reformed to overcome most of these issues through new directives and the insistence of the AEC, Portal, Penney and other notables within the AEP, such that "most of the frustrations had by…[1951]…been overcome."[301] Tellingly, in attempting to provide

[294] Lord Cherwell, HL Deb 05 July 1951 vol. 172 cc670-9
[295] Gowing, (1) (1974), p.434
[296] Gowing, (2) (1974), p.431 & Gowing, (2) (1974), p.349
[297] Gowing, (2) (1974), p.72-74
[298] Ibid., p.84
[299] Ibid., p.474
[300] Ibid., p.74
[301] Gowing, (1) (1974), p.424

evidence of the merits of an independent corporation to Attlee in 1951, Cherwell complained that "as to concrete instances of delay [,] no doubt a good many could be produced were not Portal and his men busy clearing them up."[302] The fact that this was Portal and (to a lesser extent) Penney's role as administrators appeared lost on Cherwell. Gowing recounts that "during the summer of 1952 Cherwell's staff searched for all the evidence they could find of delays and staffing difficulties in the organisation. There was some…but not nearly as much as Cherwell had hoped for."[303] Therefore, Gowing bluntly concludes that Cherwell's drive for the foundation of the UKAEA "was built on a misreading of the past."[304]

Having administered HER from 1947, Penney's reflections on the organisation of HER and the prospect of an independent atomic corporation are illuminating as he appears to have changed his mind over time. For instance, he recommended on 23rd November 1951 that "the advantages of a Corporation outweigh the disadvantages," whereas in a draft letter to Cherwell dated 14th May 1953, he could not "decide whether…[HER] will go better in an Atomic Energy Corporation or not."[305] The antagonism Penney personally expressed against the MoS in 1950-1951 coincided with great difficulties in getting staff and material: it is therefore unsurprising that he could "see great merit in a corporation" when presenting the idea from Cherwell to the AEP during this time.[306] The main frustration expressed by a senior HER colleague was the desire for HER to "be openly atomic, and have an established Priority."[307] However, a more considered response to the matter from a HER committee determined the main problem confronting HER to be a "lack of effective priority," which was an issue with the "statement of Government policy" rather than organisational structure.[308] Therefore, HER as a body concluded in 1951 that "an Atomic Energy Corporation will create more difficulties than it will solve."[309] As the issues directly related to the MoS abated from 1951 and after the Hurricane tests, the potential disruption that the reorganisation would impose came to the fore.[310] This resulted in Penney admitting in 1953 in an unsent draft letter of his own "confused state of mind" as he attempted to reconcile his own experiences with the future potential needs of the organisation, and the fact that many of his staff favoured remaining in the MoS. [311] In the balance

[302] TNA, PREM8/1556, Lord Cherwell to Prime Minister, 06/03/1951
[303] Gowing, (1) (1974), p.431
[304] Ibid., p.435
[305] TNA, ES1/329, CE/HER to CS/HER – Proposed Atomic Energy Corporation, 23/11/1951 & TNA, ES1/427, Draft Letter – Penney to Lord Cherwell, 14/05/1953
[306] TNA, ES1/329, To All Superintendents – William Penney, 14/11/1951
[307] TNA, ES1/329, CE/HER to CS/HER – Proposed Atomic Energy Corporation, 23/11/1951
[308] TNA, ES1/329, Re-organisation of Atomic Energy – E3, 11/12/51
[309] Ibid.,
[310] Gowing, (2) (1974), p.74 & 83
[311] TNA, ES1/427, William Penney to Lord Cherwell, (n.d.)

was the link between the MoS, with its discretion over staffing of other defence projects, against scientific connections with the rest of the AEP and the potential for greater organisational flexibility.[312] Penney concluded pessimistically that "In either case, Aldermaston will be adversely affected…[but remaining with the MoS]…will have less serious consequences."[313]

Conclusion

Despite the reservations of Penney and the opposition of many HER staff, the Atomic Weapons Research Establishment was incorporated as part of the UKAEA in 1954. This move brought to an end the "very peculiar" organisational structure that had developed around HER over time.[314] In terms of the hypothesis drawn from the secondary literature, this chapter has traced how the HER project had initially benefited from starting off as a clandestine sub-section of the ARD, forming into its own institution under the MoS after the split from the ARE in 1950. While rightly praised as providing HER an adequate skills base for tacit knowledge reliant tasks such as explosive casting, HER quickly outgrew the confines of a subdivision of the ARD. Archival material demonstrates that the HER project continued to suffer from skill shortages despite this foundation, both amongst scientists and its production workforce. In addition, the HER's creation from within the ARD meant that it continued to compete with conventional projects for priority and had to routinely justify its existence amongst policy makers. This manifested with the protracted contest over maintaining and asserting industrial priority.

This analysis further explored the numerous negative consequences of the overburdensome secrecy imposed upon the HER project. This included a lack of representation for HER on key policy making institutions such as the Defence Policy Research Committee and initially no direct representation on the Atomic Energy Council. This created the conditions for the AEP and HER's needs to be frequently challenged by competing defence projects and ministries, most clearly embodied by Tizard's attempts for HER to be deprioritised in favour of the ROTOR programme. With unclear direction from central government, competition over resources reflected the role that individuals with strong institutional interests such as Tizard, Portal and other members of the Chiefs of Staff played in a dysfunctional policy making environment. Therefore, the

[312] Ibid.,
[313] Ibid.,
[314] Gowing, (2) (1974), p.421

"obstruction…[encountered by HER] from organizations within the British state whose priorities were different" noted by MacKenzie and Spinardi, was the product of secrecy and further enhanced by poor initial planning which required the nuclear weapons project to consume more staff and resources than initially estimated.[315] However, secrecy also meant that figures such as Penney and Portal had direct lines of communication to the Prime Minister and could therefore present their concerns over skill shortages directly to the most senior levels of government, thereby overriding rival institutional concerns. This would prove to be an influential factor in deciding the principal-agent relationship in later periods.

This chapter also assessed claims, made most notably by Cherwell, that the civil service was responsible for slowing the progression of the atomic programme. It was argued that this belief was the result of the sequential difficulties experienced in recruiting skilled staff, problems encountered with priority and secrecy and the necessity of politically advocating for HER's interests. In order to overcome these challenges, the HER project had to repeatedly assert its high priority, but contend with internal administrative matters such as pay, transport and housing within the weapons project. While these may have been unglamorous, these were amongst the chief concerns for HER's leadership due to the necessity of maintaining the prerequisite skill base necessary to conduct their work. The intense effort expended to recruit staff created general discontent among senior figures in the AEP with the civil service. Penney expressed his concerns about HER's inability to modify pay to rectify skill shortages and these issues were noted by Lord Cherwell, which in turn led to the transition to the UKAEA. However, many of these problems were temporary issues due to extraordinary circumstances and were being addressed. By the time of the transition to the UKAEA, Penney was uncertain as to whether it would provide a substantial benefit to the future of the nuclear programme.

The transition to the UKAEA was intended to provide the nuclear weapons establishment with the autonomy to manage itself more efficiently. The culmination of the processes in this chapter led to the perceived need to improve the autonomy of the weapons establishment to aid recruitment and retention. This highlights the contemporary perceived importance of knowledge management issues. Nonetheless, as will be seen in the next chapter, the new system introduced a new series of problems. By tracing the British nuclear weapons efforts from their foundation to the end of Operation Hurricane, this chapter has examined both the dysfunction of nuclear weapons policy at a political level and the effective operation of the HER establishment on an administrative

[315] MacKenzie and Spinardi, (1995), p.71-72

level. This contrast helps explain the differing perceptions of both the relative efficiency and inefficiency of the initial efforts of the British nuclear weapons programme.

Chapter 4: AWRE and the Thermonuclear Programme (1954-1958)

Introduction

This chapter uses process tracing to highlight how the British nuclear weapons establishment passed from a crisis in staff morale in 1954 to another in the early 1960s while it undertook its thermonuclear programme. It will be demonstrated that both of these crises were rooted in doubts about the sustainability of Britain's nuclear weapons efforts and they threatened to denude the establishment of its newly created base of specialised staff when they were most needed. While various initiatives and good leadership allowed the Atomic Weapons Research Establishment (AWRE) to deliver on the British thermonuclear programme promptly, this chapter will trace how the measures taken established two ongoing processes that had serious repercussions for the establishment going forward. Firstly, the establishment's workforce quickly expanded to its peak levels, but only temporarily to swiftly deliver results. As this cohort acquired testing experience, it was in the institution's interest to retain as many of them as possible. Secondly, providing continued work for the staff at Aldermaston as initially promised in 1954 would remain a perennial issue and would go on to have significant future consequences for UK nuclear weapons policy as AWRE advanced its institutional interests.

Initially, this chapter will trace the combination of drivers that led successive Conservative administrations in the 1950s towards strongly favouring developing thermonuclear weapons. However, the need to complete the thermonuclear programme before the implementation of a test ban treaty meant the project was conducted at pace. This section confirms the hypothesis that due to the perceived pressing need for a thermonuclear capability and the time in which the programme had to be completed in, greater resources were granted to AWRE compared to during the HER project. While complaints about funding and priority are notably absent from AWRE during this period, the tempo with which results had to be produced in placed great strain on the establishment.

The next section will assess the claim that AWRE suffered from a crisis going into the thermonuclear programme. Due to the workload imposed upon AWRE, rapid expansion of the staffing levels at Aldermaston was required. This thesis concurs with Arnold and Pyne that AWRE found itself in a morale crisis from 1953-1954 but will argue that this was primarily the result of the

transition to the United Kingdom Atomic Energy Authority (UKAEA) and lasted longer than otherwise suggested.[1] It will be demonstrated that this 'crisis' threatened staff recruitment and retention and that senior figures believed that it threatened the progress of the thermonuclear programme. Short term solutions to improving morale, such as pay incentives and housing are assessed, in addition to the role William Cook played in advancing the programme.

Rather than these factors, it will be argued that to overcome morale problems at AWRE, the offered solution was to 'diversify' the work of Aldermaston. This was primarily because AWRE's skilled workforce, who increasingly identified as 'weaponeers,' were worried over the future security of their jobs and demanded reassurance. While promises were made to prevent redundancies through further work, these projects repeatedly failed to manifest before British nuclear weapons work was reduced. Although not immediately apparent, the combined interlinked processes of rapid expansion for the thermonuclear project, an apparent institutional crisis due to the transition to the UKAEA and staff identifying as weaponeers due to their alleged embodied tacit knowledge would have long term cyclical repercussions as it established a need to undertake heterogenous engineering.

The closing section of this chapter evidences a renewal of this cycle after the moratorium on atmospheric testing and the US–UK Mutual Defence Agreement in 1958. Greater US cooperation brought to the fore longstanding fears over AWRE's future that had temporarily been suppressed by the influx of work brought by the thermonuclear programme. Although AWRE's management again promised diversification as the solution to these difficulties, the establishments senior leadership recognised that they would have to be far more proactive in acquiring additional work. This was necessary not only to fulfil prior promises but to retain skills necessary to maintain a nuclear arsenal. This established a recurring process that would repeat until 1993.

In terms of the sources used in this chapter, it is worth considering that many of the files remain classified, even compared to the prior fission programme. Nevertheless, recently declassified files at the National Archives provide Aldermaston's internal management's perspective into the era. While some gaps in the record remain, these cover more technical aspects of the programme which is not the focus of this thesis.[2] Of more concern is that Arnold notes "that many of the most important and sensitive documents [for the period] were destroyed by Aldermaston during a 'reorganisation' in the 1960s."[3] In addition, neither William Penney nor William Cook's personal files

[1] Arnold and Pyne, (2001), p.76
[2] The individual/s responsible for the scientific innovations that enabled that British thermonuclear programme remains a contentious topic. See Arnold and Pyne, (2001), p.93 & Dombey and Grove, (1992)
[3] Ahmed, (2001)

for the period are available.[4] Nevertheless, from the archival material available, a picture emerges of how AWRE entered into a crisis in 1954, stabilised and then re-emerged into a crisis of confidence by 1962.

Consistent Political Commitment

The priority devoted to the thermonuclear programme, in contrast to the fission programme, was more consistent and less secretive. While initially beneficial, this had consequences for AWRE as it quickly expanded to a level that would prove unsustainable going forward. The ability to acquire this priority was the result of a sustained change in the Conservative party's political thinking in relation to nuclear weapons and defence in the 1950s combined with the potential explosive yields of thermonuclear devices.[5] The American's Ivy Mike test of 1952 had demonstrated the viability of fusion devices and the Castle Bravo tests of March 1954 proved the practicality of thermonuclear weapons. Soviet nuclear developments followed apace, with a test in August 1953 measured at around 400kt. While the British government were aware that the device was not a fully-fledged Ulam-Teller type design, the Joint Intelligence Committee believed that the test indicated the Soviet's intention and capability to progress their thermonuclear programme imminently.[6] Further adding to the pressure to follow a similar course, Penney briefed the cabinet in March 1954 that thermonuclear weapons would provide great economies in fissile material and greatly increase (to a practically unlimited degree) the destructive power of nuclear weapons.[7] This was also paired with a change in attitude towards the feasibility of the UK building a hydrogen bomb: In 1952, Cherwell had briefed the cabinet that a programme would be "well beyond" the capacity of the UK, but had changed his mind by April 1953, instead arguing in favour of the flexibility, destructive power and potential economies that hydrogen bombs could provide.[8] New information obtained from American tests led the Chiefs of Staff to state in 1954 that "the cost of producing these weapons should not be beyond our financial capabilities."[9] A Cabinet meeting in

[4] Arnold and Pyne, (2001), p.94
[5] As will be seen, particularly supported by Duncan Sandy.
[6] TNA, CAB158/17/1, Soviet and Satellite War Potential, 1954-1958 – Report by Joint Intelligence Committee, 15/02/1954
[7] TNA, CAB130/101, GEN 465 Meeting, 12/03/1954
[8] Simpson, (1986), p.102 & TNA, CAB127/203, Lord Cherwell to Prime Minister, 17/04/1953
[9] TNA, CAB129/69, United Kingdom Defence Policy, 31/05/1954

July of 1954 discussed how the net additional cost of a thermonuclear programme would only be an additional £10 million. [10]

The strategic implications of the significantly increased yields offered by thermonuclear weapons were quickly realised. William Penney relayed to the Cabinet in March 1954 that the US Air Force still partially viewed fission weapons as a powerful augment to strategic bombing, but one that required large amounts of uranium which there was thought to be a limited amount globally.[11] This view, combined with opportunity costs that would be accrued by pursuing fission weapons at the expense of other programmes had previously led figures such as Tizard to argue in favour of resources being devoted to air defences rather than Britain's nuclear programme.[12] However, a belief in the ability of the RAF to adequately prevent destruction to mainland Britain receded in the face of the destructive potential of even a single thermonuclear detonation.[13] With growing realisation of the implications of thermonuclear technology, the Chiefs of Staff further briefed the cabinet in July 1954 that the "world situation has been completely altered."[14] This conception of nuclear pre-eminence and the need for deterrence was typified in the 1955 Strath Report which fully cemented the destructive potential of thermonuclear weapons with its conclusion being that "overwhelming and immediate retaliation with it [i.e. hydrogen bombs] is our only reliable defence."[15]

In combination with these pressures, Churchill also believed the acquisition of thermonuclear bombs was politically important as, "influence depended on the possession of force."[16] Recalling Bevin's comments on placing the Union Jack on the fission weapon, Hennessy quotes Plowden's recollections of Churchill stating that "we must do it [develop a thermonuclear programme]. It's the price we pay to sit at the front table."[17] While conforming to great power status was a stated motivating factor, the Chiefs of Staff acknowledged the need to bolster the UK's "influence."[18] This often implicitly meant affecting the UK-US relationship which only grew in urgency after the Suez Crisis in 1956 wherein the need to tie American interests to British foreign policy goals became ever greater. For instance, in 1957, with the thermonuclear programme progressing, Edwin Plowden sent a letter to the Lord President of the Council summarising that

[10] TNA, CAB128/27, Cabinet Minutes, 08/07/1954
[11] TNA, CAB130/101, GEN 465 Meeting, 12/03/1954
[12] See previous chapter
[13] Simpson, (1986), p.95
[14] TNA, CAB129/69, United Kingdom Defence Policy, 31/05/1954
[15] Hughes, (2003), p.261
[16] TNA, CAB134/808, Committee on Defence Policy Meeting, 19/05/1954
[17] Hennessy, (2007), p.91
[18] TNA, CAB129/69, United Kingdom Defence Policy, 31/05/1954

thermonuclear weapons would allow Britain to "occupy in the military field a position vis a vis the United States" so as to avoid becoming "something like those German States that in the 18th century provided excellent mercenaries to be hired with British gold."[19] Richard Moore quotes Harold Macmillan from a Defence Cabinet Meeting in July 1958 where he stated that "the *political* [sic] target of Britain's nuclear force was not the Soviet Union at all, but the United States."[20]

In a counter-intuitive way, another factor that ensured that the thermonuclear programme retained sufficient resourcing was that it was perceived to hold the potential to save money on defence. After the Second World War, Britain's defence commitments in terms of rearmament, its remaining imperial commitments and participation in the Korean War placed a great strain on the economy. This was realised by John Slessor, Chief of the Imperial General Staff, who stated that "large, balanced, well equipped, conventional forces were not achievable in relation to Britain's economic prospects."[21] As a result, the 1952 Global Strategy Paper placed a greater emphasis on nuclear deterrence as a solution to this predicament.[22] As Maguire argues, the subsequent prevailing argument within Conservative governments of the 1950s for "those arguing that nuclear weapons could form the backbone of Britain's defences… utilized the Treasury's downward pressure on defence spending to advance their position by claiming that nuclear weapons were cheaper than conventional forces."[23] This was most clearly characterised in Duncan Sandys' (Minister of Supply) 'Radical Review' of defence spending in 1953 and eventually the famous defence White Paper of 1957.[24] Therefore, commitments towards developing thermonuclear weapons in 1954/1955 came at a time where most other aspects of the armed services were facing cuts.[25] This was repeated in 1957 where reductions in manpower through the abolition of national service were perceived to be compensated for with proposed increases in nuclear firepower.[26] These policy documents were particularly the product of Duncan Sandys, whose personal unwavering belief that a Britain relying on nuclear deterrence was the "only sane policy" both financially and militarily.[27] As Betts argues, Duncan Sandys' beliefs stemmed from his personal experiences of WW2 and were highly influential in successive Conservative cabinets.[28] This included support for an array of tactical nuclear weapons which AWRE would have to develop as "Sandys almost certainly had little or no regard for any

[19] TNA, AB16/1910, Plowden to Lord President of the Council, 20/02/1957
[20] Moore, (2010), p.28
[21] Paterson, (2012), p.16
[22] Ibid., p.16
[23] Maguire, (2012), p.562
[24] Betts, (2014), p.52
[25] TNA, CAB134/808, Committee on Defence Policy Meeting, 19/05/1954
[26] TNA, CAB129/86, Defence – Outline of Future Policy, 03/1957
[27] Betts, (2014), p.82 & p.216
[28] Ibid., p.216

distinction between nuclear and nonnuclear weapons from the perspective of their being legitimate policy options, and that he therefore believed that Britain would have been wise to retain its capacity to develop and deploy tactical nuclear weapons."[29] This meant an additional workload on AWRE as it developed a thermonuclear capability.

By a combination of the above factors, British Conservative governments in the 1950s were led towards supporting the thermonuclear programme to a greater extent than Labour with the fission programme. Simpson believes that the thermonuclear programme was therefore "subject to much greater political pressures, imperatives and constraints than the Blue Danube one."[30] These 'imperatives' meant that support for the initiative was maintained under three successive administrations with the corresponding level of financial resources and priority. In addition, prestige was publicly at stake after Anthony Eden declared that Britain would conduct a "megaton range" test in 1957.[31] Although Saunders' framework for the domestic politics of nuclear choices highlights the benefits of broad support to 'mobilise' state resources, the imperatives driving the programme at pace meant that it also faced other restrictions.[32]

Imminent Test Ban: Limited Time Frame

In contrast to financial or political backing, the most pressing factor that forced Aldermaston and Penney "to proceed at [the] upmost speed" was the potential imposition of an atmospheric nuclear test ban.[33] While opposition to nuclear weapons was gradually increasing throughout the 1950s, domestic and international support for banning nuclear testing was significantly bolstered in 1954 following the American's Castle Bravo test and the Lucky Dragon incident.[34] The first talks discussing a ban between the United States and Britain occurred in April 1954 with negotiations with the Soviets starting in 1955.[35] As recalled by Walker, Smith and Arnold and Arnold and Pyne, this placed Britain's Conservative administrations in an uncomfortable position wherein they supported a testing ban, but ideally only when the UK had developed its own thermonuclear weapons. [36]

[29] Ibid., p.121-122
[30] Simpson, (1986), p.95
[31] Anthony Eden, HC Deb 07 June 1956 vol. 553 cc1283
[32] Saunders, (2019), p.175
[33] TNA, DEFE7/923, Megaton Tests – E2, (n.d.)
[34] Arnold and Pyne, (2001), p.111
[35] Arnold and Smith, (2006), p.82-83
[36] Walker, (2010), p.5 & p.10-11, Arnold and Smith, (2006), p.82-85, Arnold and Pyne, (2001), p.108-112. A further stipulation for a test ban would that it would have to be verifiable

However, while Britain lagged behind the Soviet Union and America in terms of thermonuclear technology, it was also susceptible from the international community (primarily the United States) forcing it through moral and political pressure to abide by a test ban treaty before it was ideally ready to do so.[37] As it was not in the gift of British policy makers to dictate when an accord between the Soviet Union and the United States was reached, this meant that the thermonuclear programme would have to be conducted as rapidly as possible. As a result, the Ministry of Supply (MoS) moved in December 1955 for the Atomic Weapons Trials Executive to work for a trial date of May/April 1957.[38]

This timetable was far from ideal from AWRE's perspective as in February 1955, "Aldermaston theoreticians…[still] groped for solutions" to fundamental issues for thermonuclear designs.[39] As Arnold and Smith state, this meant that the Weapons Group at Aldermaston worked "in an atmosphere compounded equally of extreme urgency and extreme uncertainty… This sense of urgency affected everyone in the project, and prompted the most strenuous efforts from scientists, engineers and industrial workers alike."[40] Such were the theoretical uncertainties surrounding fusion tests that in 1956, Cook was only able to give a maximum possible yield, rather than predict an accurate figure.[41] The Mosaic, Buffalo, Grapple and Antler series of tests occurred in such a condensed period of time that even marginal time savings, such as several days, attracted praise while logistical delays over shipping were a cause for "getting very worried." [42]

Though the time pressures before the Short Grapple test of May 1957 were severe, the need to rapidly deliver results only intensified after initially disappointing yields. Penney believed that "one stupid mistake… must have cost something in yield, perhaps 100 kilotons or so."[43] This first thermonuclear test was not truly in the megaton range: the device's predicted yield had only been 500 kilotons even if it had performed successfully. This was also acutely embarrassing due to the fact that initial information sent from Penney to Whitehall and subsequently relayed to the press claimed Britain was now a 'megaton' power.[44] While Penney consoled himself that this test had been more

[37] Ibid.,
[38] Walker, (2010), p.6
[39] Arnold and Pyne, (2001), p.84
[40] Arnold and Smith, (2006), p.86
[41] TNA, ES1/563, William Cook to Controller of Atomic Weapons, Ministry of Supply, 15/03/1956
[42] TNA, AB41/664, AEX Minutes, 05/04/1956 & TNA, ES1/573, S.S.X.D to S.S.W.P, 17/10/1956
[43] TNA, AB16/2439, Penney to Brundrett, 20/05/1957
[44] TNA, PREM11/2858, A.J. [Aubrey Jones] to Prime Minister, 21/05/1957. As discussed in the document, no retraction was made due to the international humiliation that it would incur. This lie by omission appears to be the basis of the incorrect perception of Britain's 'thermonuclear bluff' supposedly against the Americans as argued by Dombey and Grove. Dombey and Grove, (1992). This of course was politically awkward for the British government as megaton tests were now harder to publicly justify is Britain was indeed a nuclear power.

successful than the Russian's first several attempts at a megaton range thermonuclear device, later assessments from November 1957 were more frank in that they concluded that "[the first] GRAPPLE [test] was disappointing…[and] was largely unsuccessful."[45]

After the first Grapple trials, Britain had still not achieved a true megaton thermonuclear yield device and was still far away from a serviceable weapon. As talks progressed at the United Nations the situation for AWRE became ever more desperate as there was "an overwhelming sense that time was running out."[46] A further compounding problem was the potential prospect of a nuclear weapons fissile material cut off treaty. While staged thermonuclear devices were being developed, AWRE designed an interim 'megaton range' 'layer cake' (a large mostly fission) weapon which would prove highly uneconomical if it was forced into an extended service period.[47] If conditions had been less severe, the ideal testing regime foresaw staggered detonations "in both megaton and kiloton range[s] for a period of at least 2 years."[48] While Cook believed that "the quickest and most economical way to reach our final design is by a system of step-by-step experimentation," it was not perceived that there would be enough time for this method.[49] Penney acknowledged in autumn 1957 that "if there was no threat from the political side to stop the trials, AWRE would not be anxious to force the type of crash programme they were at present undertaking."[50]

After rapidly redesigning elements of the previously failed Short Granite device, another test, designated Grapple X, was ready for 8th November 1957.[51] This test was a source of considerable anxiety as Penney admitted that "if the results were very poor… AWRE would then need time to re-consider the whole situation."[52] Two failures in a row would have suggest a fundamental flaw in Aldermaston's approach to thermonuclear design. In the event, the test produced Britain's first truly megaton yield and was considered "highly successful from a scientific standpoint." [53] While this represented significant progress, the design "did not in any way represent

As a result, information was "limited to the very small circle of officials already in the know." – See TNA, DEFE7/922, Untitled Draft Letter – Marked E26, 17/07/1957 & TNA, PREM11/2858, Antony Head to Prime Minister, 20/12/1956

[45] TNA, AB16/2439, Penney to Brundrett, 20/05/1957 & TNA, DEFE7/921, Results of Operation GRAPPLE and GRAPPLE-X, 28/11/1957

[46] Arnold and Pyne, (2001), p.152

[47] Ibid., p.153, Although this fear was partially alleviated considering the Declaration of the Washington Conference of October 1957

[48] TNA, AB16/2439, Nuclear Tests, 21/06/1957

[49] TNA, DEFE7/922, Further Information on Proposals for Megaton Tests – E171, (n.d.)

[50] TNA, DEFE7/922, Trials Policy – E148, (n.d.)

[51] Arnold and Pyne, (2001), p.161

[52] TNA, DEFE7/922, Trials Policy – E148, (n.d.)

[53] TNA, AIR2/13733, Progress Report on Nuclear Weapons, 30/09/1957

a Service warhead."[54] Instead, "the success of our November trial...[had] shown the scientists that they are on the right track."[55] Although Aldermaston's understanding of thermonuclear implosion devices had advanced considerably by January 1958, "the achievement of…a warhead of a 1 megaton within the weight of one ton and immune to countermeasures…[would] require [a] further series of trials."[56] The Grapple Y test, a further iterative improvement was scheduled for April 28th 1958, which was "the earliest date that AWRE…[could] be ready for the trial."[57] However, as Aldermaston progressed towards delivering on its operational requirements, similar advances were being made towards a testing moratorium.

On 31st March 1958, the Soviets announced a unilateral halt to their thermonuclear tests with the implicit challenge that this should be matched by the West.[58] Shortly thereafter, America announced that it would suspend its testing programme of six months.[59] This created an intense period of negotiation and coordination wherein Britain had to reconcile the objectives of its nuclear programme with the dawning political reality that testing would be imminently halted. While beyond the scope of this thesis, Walker provides an account of how this led the Macmillan government to pursue the overlapping objectives of delaying a Western moratorium until after the AWRE autumn testing programme, persuading the Americans to share more information on primaries and radiation immunity and at the same time, keep the prospect of a testing moratorium imminent.[60] With the concession that negotiations on a test ban should start at the end of October 1958, a hard deadline was placed upon British atmospheric testing so that "political considerations took precedence over the scientific imperatives" for the timings of final Grapple Z tests.[61] This section has confirmed the hypothesis that despite consistent political support, the negotiations for a test ban forced AWRE to undertake what contemporaries often described as a crash programme.[62]

[54] Ibid.,
[55] TNA, DEFE7/922, Letter to Prime Minister of Canada, New Zealand & Australia – E216, (n.d.)
[56] Arnold and Pyne, (2001), p.161-162 & TNA, DEFE7/922, Draft - Further Information on Proposals for Megaton Tests – E165, (n.d.)
[57] TNA, DEFE7/923, Macklen to Richard Powell, 03/03/1958. The initial test date had been scheduled for March 29th, but an "accident at the Lithium Six Deuteride building at Aldermaston" meant that it was delayed until the end of April. See also TNA, DEFE7/2379, Lloyd to Macklen, 02/01/1958
[58] Bunn, (1992), p.241
[59] Walker, (2010), p.66
[60] Ibid., p.71-90
[61] Ibid., p.65
[62] TNA, DEFE7/923, Macklen to Richard Powell, 03/03/1958 & TNA, DEFE7/922, Trials Policy – E148, (n.d.)

Resources at AWRE: Limited Oversight & High Priority

Unlike with the fission programme, financial constraints and competition with other government ministries for priority do not appear to have effected AWRE during the thermonuclear project.[63] In the available files during the era, senior AWRE staff do not complain about the funding they received. This is perhaps unsurprising given that the interdepartmental Nuclear Test Policy Committee clearly understood government policy from 1955 onwards to be "to possess [an] independent [thermonuclear] deterrent and this is [the] highest priority."[64] Another factor in AWRE's favour was that the government's intention to acquire thermonuclear weapons was made public in February 1955.[65] The open announcement inevitably created political imperatives towards devoting sufficient resources to the endeavour.[66] Correspondingly, letters between Penney and Sir Donald Perrot (UKAEA's head of Finance and Administration) from 1956 and 1958 about staff pay consistently acknowledge the continuing need for AWRE to expand its staff and deliver results as promptly as possible, premised on government policy.[67] The intentions of the principal clearly aligned with the agent's interests. In August 1954, AWRE's staff total stood at 3908 but this had nearly doubled to 7589 by March 1958.[68] Nonetheless, manpower consistently lagged the complement that Aldermaston was permitted (see Annex 1). Given the high priority and rapid expansion, spending quickly increased at AWRE without a corresponding increase in oversight.

In terms of imposing some financial limitations on the programme, predictably, the Treasury was the main actor and at various stages, seen by nuclear programme insiders as the main threat to their testing programme. One of the highest-level challenges to the scale of spending on Britain's thermonuclear programme came in early January 1956. Harold Macmillan in his then role as Chancellor raised a series of questions to the Prime Minister about the level of spending involved in Operation Grapple: Macmillan complained that the tests would cost a "very large amount" and asked why three megaton tests were necessary where one could presumably suffice.[69] This suggestion is not explicitly discussed in Macmillan's memoirs, but presumably arose from financial

[63] Apart from AWRE staff pay – see section on retention.
[64] TNA, DEFE7/921, Macklen to Powell – Nuclear Test Policy Committee, 18/11/1957
[65] MacLellan, (2017), p.34
[66] Compared to the secret fission programme. See Churchill's speech to parliament in March 1955 where further political capital was staked on their acquisition. Winston Churchill, HC Deb 01 March 1955 vol. 537 cc1893- 1905. Cabinet minutes suggest that there was little faith in keeping the project secret in any case. TNA, CAB128/27, Cabinet Conclusions, 08/07/1954
[67] TNA, AB16/1768, Cook to Perrott, 09/06/1956 & Penney, (1968), p.298
[68] TNA, AB16/2303, Comparison of Actual with Estimated Strengths, (n.d.)
[69] TNA, PREM11/2857, Macmillan to Prime Minister – Trials of British Megaton Warheads, 12/01/1956

and political concerns due to the test preparations coinciding with a minor budgetary crisis and the need for a broad reduction in defence spending in early 1956.[70] Nevertheless, this suggestion was quickly rebuffed with the move being opposed by Walter Monkton, the new Minister of Defence.[71] The antagonism between Britain's nuclear establishment and the Treasury can be seen for example when the UKAEA and MoS were prompted to supply cost estimates to the Prime Minister for the costs of ongoing tests after Grapple X in early 1958. Simply providing an estimated budget was "first blood to them [the Treasury] against us on this matter, and the whole of our policy," thereby posing a "danger" to nuclear testing.[72]

In terms of the Treasury imposing meaningful limitations on routine and capital spending projects at Aldermaston, the sense of overriding priority and the inability to provide serious oversight becomes apparent from the available sources. Even before the start of the thermonuclear programme, Maguire quotes a Treasury official from 1953 who noted that they "cannot help feeling that the first Aldermaston reaction to any new afterthought is to demand a new building automatically instead of making every effort to make do with the buildings already available or in hand."[73] The file for 'Approvals for capital projects at Aldermaston and other Weapons Group establishments' between 1955 and 1960 routinely records approval for spending projects without serious contestation.[74] For instance, a May 1955 UKAEA note to the treasury reports a range of new projects and cost overruns against estimates. The request for spending authorisation concludes that "these tests cannot be delayed and the buildings required here will have to be built as quickly as possible."[75] In response to this lengthy series of requests, the Treasury simply briefly approved of the proposal as the works were "vital to the priority programme."[76] The apparent frustration with the inability to provide oversight on Aldermaston spending is evident in a letter dated 28th May 1956

[70] Macmillan, (1971), p.10-11. Given that broad defence spending cuts were agreed between Monkton and Macmillan that would pre-empt the defence White Paper of 1957, Macmillan's call for scaling nuclear testing can possibly be seen as a negotiating stance taken against the MoD to leverage wider cuts, instead of a serious proposal.
[71] TNA, PREM11/2857, Walter Monkton to Prime Minister - Trials of British Megaton Warheads, 09/01/1956. The technical merits for reducing testing were also unlikely to succeed given that a few days before Macmillan's proposal, Monkton had penned his name to a letter to the Prime Minister forwarding the AWRE, UKAEA, MoS and MoD arguments for the upcoming Grapple tests, justifying their scope and scale.
[72] TNA, DEFE7/922, Further Information on Proposals for Megaton Tests – E171, (n.d.) & TNA, DEFE7/922, Macklen to Powell, 09/01/1958
[73] Maguire, (2012), p.526
[74] TNA, EG1/345
[75] TNA, EG1/345, Michaels to Beighton, 07/05/1955
[76] TNA, EG1/345, Beighton to Michaels, 11/05/1955

from the Treasury, wherein rising estimates for a new radioactivity laboratory are approved, but it's noted that "we [the Treasury] have little option but to agree to the new estimate."[77]

While limiting funding for the development of thermonuclear weapons was never seriously considered, the ongoing costs for testing, especially Grapple Y, Z and predicted future trials did lead to questions being raised about the ongoing financials of the project in 1957-1958. The Nuclear Test Policy Committee had to continually seek approval of their financial plans for testing from both the Prime Minister and the Chancellor.[78] This imposed some additional uncertainty on the future of trials as each test proposal had to be sequentially justified and approved as the total costs accumulated.[79] For instance, while Grapple X had proven the viability of British thermonuclear design ideas, the Minister of Supply had to push on 25th November 1957 that further tests were needed to develop "a device which is light, economical in fissile material and immune to counter-measures."[80] Beyond weapon design, the MoS also reported in the same month that there was also "big Service demand for indoctrination and Target Response," which would involve test detonations of all of AWRE's fielded designs.[81] Tests were envisaged as occurring for the foreseeable future on a four monthly basis.[82] The exorbitant costs involved also created questions over departmental spending. With the Grapple trials ongoing, the MoS was "in effect, supporting the extra costs of a large military force on the other side of the world," to the detriment of all its other programmes.[83] However, rather than potentially arguing for the projects cancellation, the issue of cost was raised within the context of creating a more equitable distribution of the expenses across government departments.[84]

When detailing the costs of maintaining this testing programme, staff salaries and other expenses accrued by Aldermaston were not given great consideration as not only were they relatively insubstantial compared to the fissile material and logistics involved in trials, but resources devoted to them were considered standing costs that would have been accrued anyway.[85] As a result, Aldermaston did not suffer the same resource deficiencies it had during the fission programme. Due to it being a lack of a problem, Aldermaston files of the era do not extensively

[77] TNA, EG1/345, DM.35/70/07, 28/05/1956
[78] TNA, DEFE7/922, Draft Minutes to the Prime Minister, (n.d.)
[79] TNA, DEFE7/2379, Provision for Nuclear Tests, 16/01/1958, TNA, DEFE7/2379, Megaton Tests – E54, (n.d.), TNA, DEFE7/2379, Untitled – E93, (n.d.), TNA, DEFE7/2379, Megaton Tests – September 1958 – E110, (n.d.)
[80] TNA, DEFE7/922, Duncan Sandys to the Prime Minister, 25/11/1957
[81] TNA, DEFE7/922, Cabinet Nuclear Tests Policy Committee – Future Trials at Maralinga, 14/11/1957
[82] Ibid.,
[83] Ibid.,
[84] TNA, DEFE7/922, Nuclear Tests Policy Committee Minutes, 18/11/1957
[85] TNA, DEFE7/922, Analysis of Expenditure from December 1957 to March 1959 Inclusive, (n.d.) & TNA, DEFE7/923, Brundrett to Minister, 20/05/1958. As will be seen, this did not mean that Treasury would not seek to avoid minor staff related expenses, even when they have been a significant boon to AWRE.

discuss or complain about funding. For example, when cuts to government expenditure were discussed at an Atomic Energy Executive (AEX - the successor to the Atomic Energy Council) meeting in 1956, the Weapons Group's privileged position is evident: while the Production and Research Groups of the UKAEA had their respective executives justify their operations and scale back planned projects, Penney was able to swiftly reject cut-backs on the grounds that they would be false economies or create shocks to morale, but primarily that it would mean "fore-going the hydrogen bomb tests," which would clearly be unacceptable.[86] Other benefits enjoyed by Aldermaston during this era that were notably absent from the fission programme was their ability to second staff from the UKAEA, armed services and other defence research establishments.[87] However, this facility was only provided in the spring of 1958, during the final sprint towards delivering devices for Grapple Z.[88] While temporarily beneficial, the process of lavishly resourcing AWRE during the mid-1950s made future conflict over eventual reductions near inevitable.

Unsustainable Tempo

Given the successful outcome of the later Grapple tests and the settlement of the US-UK Mutual Defence Agreement in 1958, Walker believes that "testing constraints do not appear to have unduly harmed the UK weapons programme."[89] However, the pressure exerted by the imminence of a test ban meant that a number of expedients were taken by AWRE to deliver megaton devices. Contemporaries, such as Macklen, lamented in 1958 that the "trials… [were] not designed as a crash programme to fit in everything that is humanely possible before a sudden stop to nuclear tests as a whole."[90] Cook was complaining as early as late 1955 that the thermonuclear programme schedule "means compressing a three year development programme into just over a year."[91] The physical infrastructure at Aldermaston sometimes failed to keep pace with the programme. In letters to the Treasury requesting further facilities, the Materials division complained in December 1955 that as: "the staff of the Division has more than doubled in the last twelve months. Work is being carried out

[86] TNA, AB41/664, AEX Minutes, 26/01/1956
[87] TNA, ES1/1503, J. E. Adamson to C.P.O., 31/07/1958 & TNA, ES15/5, Board of Management Minutes, 02/04/1958
[88] Hence it did not help with the recruitment problems from 1954 onwards at AWRE that are discussed below.
[89] Walker, (2010), p.107
[90] TNA, DEFE7/923, Macklen to Richard Powell, 03/03/1958
[91] TNA, ES1/563, Draft letter to Cook to Gen. Fredrick Morgan, (n.d.) Document undated but references flights for Green Bamboo needing to start in 3 months, which in the appendix, are listed as needing to commence in January 1956.

in unsuitable temporary buildings scattered all over the establishment, and some processes (e.g. carbonyl plating) are being carried on under unsafe conditions. Even lecture rooms are being congested with laboratory work."[92]

The rush to deliver thermonuclear devices had consequences. In early 1956, it was suggested that inadequate thought was being devoted to safety features being implemented in new physics packages compared to that given to the problem leading up to Hurricane.[93] This became evident with Violet Club, which was rushed into service and infamous upon delivery to the RAF: it had to be filled with ball bearings to prevent criticality accidents.[94] Orange Herald, a boosted fission device, was described in safety terms as a "major difficulty" shortly before it was sent for testing on Christmas Island.[95] While concerns over the safety of the Grapple devices were less prominent, progress reports repeatedly assert that further testing was needed to produce a "safer" device.[96] After Grapple X, a further document suggests that "two to three years" of testing were needed to differentiate between a "relatively safe" warhead for Blue Streak or Blue Steel, compared to a "safe" device.[97] These flaws, combined with the superior efficiency of American designs likely contributed to the latter being chosen to equip Britain's thermonuclear arsenal. Baylis and Stoddart go as far as to partially credit the failure of the first Grapple test to "pressure from the government" to beat the imposition of a test ban, which led AWRE to rush the process.[98]

The push to deliver material for AWRE's programme was also not without incident. Most infamously, the production of tritium at Windscale was a significant factor in the 1957 fire, leaving Arnold to conclude that "Britain was not alone in taking risks under inexorable atomic pressure."[99] Even at Aldermaston, an "accident at the lithium six deuteride building" in part credited to the pace of the effort, further "set back their programme."[100] According to Simpson, the thermonuclear programme also meant that "the acceleration of experimental work also let to a limited sacrifice of

[92] TNA, EG1/345, Extension of Laboratory and Offices, 06/12/1956
[93] For example, see TNA, ES1/573, Grapple – Megaton Service Weapon, 10/09/1956
[94] McIntyre, (2006), p.35. See also TNA, AIR2/13733, Progress Report on Nuclear Weapons, 30/06/1957 - progress report state that "providing in-flight safety will be very difficult."
[95] McIntyre, (2006), p.32-33. This was apparently a considerable enough concern that due to the "touchy" nature of Orange Herald, an Aldermaston scientist questioned whether it was prudent to have a "criticality expert" on hand with inoculations." TNA, ES1/573, Operation Grapple - R.A. Assembly and Criticality Problem, 11/09/1956
[96] TNA, AIR2/13733, Progress Report on Nuclear Weapons, 09/1958 & TNA, AIR2/13733, Progress Report on Nuclear Weapons, 31/12/1957
[97] TNA, DEFE7/923, Macklen to Richard Powell, 03/03/1958
[98] Baylis and Stoddart, (2015), p.67-68
[99] Arnold, (2007), p.26, 31 & 158
[100] TNA, DEFE7/2379, Lloyd to Macklen, 02/01/1958

stockpile numbers in favour of development devices" in the short term.[101] However, as will be seen, rather than material or resources, the forced tempo of the programme placed the greatest strain on AWRE's ability to expand as an organisation to cope with their new work.

The State of AWRE: Growing Pains

Multiple Tasks: Overburdened Establishment

As the Churchill Conservative government edged towards a decision in favour of developing thermonuclear weapons in the latter half of 1954, the UKAEA had already started "considerable preliminary work…[with some] done before [the announcement]."[102] At an AEX meeting on 18th March 1954, well before a definitive political decision had been made, Penney and the other leaders of the AEP discussed what would be required for a speculative delivery date for producing a hydrogen bomb in 1956.[103] Preliminary measures that were to be implemented included securing supplies of and stockpiling tritium, deuterium and thorium, developing new implosion devices for primaries and acquiring new thermonuclear test sites.[104] According to Arnold and Pyne, this was a boon to the Weapons Establishment as by 1953, the establishment had struggled to establish a long term plan to sustain itself which was causing a perilous collapse in morale.[105] Penney, who had been considering leaving AWRE near the completion of the HER project, was once again tempted to search for an academic placement.[106]

Even with this preparatory work, AWRE's task was formidable going into the thermonuclear programme as the requirements on the organisation were manifold and complex. Although new work would give a new impetus to the organisation, it added to the "already crushing programme" at AWRE.[107] The complexity of the thermonuclear programme itself was exacerbated by the requirement of "contributing to the deterrent" at the earliest opportunity, thereby requiring the creation of an interim capability if thermonuclear efforts were halted by any arms control treaties.[108]

[101] Simpson, (1986), p.99
[102] TNA, AB16/2439, Rawlinson to Phelps, 14/07/1959
[103] TNA, AB41/514, AEX Minute Reference 54/3, 18/03/1954
[104] Ibid.,
[105] Arnold and Pyne, (2001), p.76
[106] Ibid., p.76
[107] Ibid., p.76
[108] TNA, PREM11/2857, Trials of British Megaton Warheads, (n.d.)

Therefore, the requirements from the military through the MoS to AWRE were to simultaneously fulfil multiple different operational requirements of warheads, ranging from improved fission devices (OR1127 – issued November 1953), interim megaton devices for gravity bombs (OR1136 – issued 1954), a megaton warhead for Blue Steel (OR1141 – issued 1954), a lightweight megaton warhead for Blue Streak (OR1142 – issued July 1955) and extremely lightweight fission warheads for tactical applications (OR1140 – issued June 1955).[109] Fortunately, some of the research fulfilling operational requirements did have cross-applicability: lighter and more efficient fission devices served as better primaries and were fitted into later thermonuclear devices.[110]

AWRE's task was also made harder by the organisation's limitations in regards to their theoretical knowledge on thermonuclear weapon design, where "they would 'start on a common level of ignorance'."[111] Some of the desirable requirements for a service for OR1141 were well beyond the scope of AWRE's theoretical knowledge in 1955; ideally, a deployed service warhead had to weigh one ton and be immune to premature detonation caused by neutron radiation from a nearby nuclear explosion.[112] Attaining these features would be no small task, given that these requirements were relatively advanced and that before Grapple, Britain's knowledge of thermonuclear weapons remained "theoretical and unsupported by experimental evidence."[113] AWRE's limitations were also evident in that they also pursued until 1957 the concept of a 'layer cake' type thermonuclear device (referred to as Green Bamboo or 'Type A') at the same time as developing the Ulam-Teller two stage radiation compression configuration (referred to 'Type B' and Green Granite until the first Grapple series).[114] While it had been intended to deliver a 'Type A' device as early as possible, getting the concept to work proved "much harder to get the thermonuclear side going than we had thought."[115] Due to uncertainties over how to proceed and time pressures, multiple paths were pursued simultaneously. Although beyond the scope of this thesis to provide a detailed technical history of weapons development (much of which remains

[109] McIntyre, (2006), p.26 & p.62. As made clear by McIntyre, OR1136 was the requirement for the system rather than the warhead but had to be fulfilled by a number of expedients that were not initially envisaged by the operational requirements. TNA, AIR2/13733, Progress Report on Nuclear Weapons, 30/06/1957
[110] Simpson, (1986), p.96 & Arnold and Pyne, (2001), p.136
[111] Arnold and Pyne, (2001), p.49. Quoting John Corner, an Aldermaston physicist.
[112] TNA, DEFE7/921, Further Information on Proposals for Megaton Tests, 02/11/1957 & TNA, AIR2/13733, Progress Report on Nuclear Weapons, 30/09/1957 - Thereby making it resistant to nuclear tipped missile defence measures. The weight requirement would also make it suitable for mounting on missiles like Blue Streak and Blue Steel.
[113] TNA, PREM11/2857, Macmillan to Prime Minister – Trials of British Megaton Warheads, 12/01/1956
[114] Arnold and Pyne, (2001), p.93 & Moore, (2004), p.7
[115] TNA, AB16/2439, Penney to Brundrett, 20/05/1957 & TNA, PREM11/2857, Trials of British Megaton Warheads, (n.d.). The idea had fallen out of favour after the Mosaic tests in mid-1956 as the presence of Lithium deuteride failed to significantly increase the yield of the tested devices.

classified), this has served to illustrate the heavy burden of work imposed upon AWRE, beyond continuing to deliver upon Blue Danube devices.

The First "Crisis" in Morale

If the amount of work expected from Aldermaston had never been higher, the Weapons Establishment were also poorly placed to take it on. Arnold and Pyne claim that there was an ongoing "crisis" in Aldermaston from 1953 that was eventually stabilised by the leadership of Penney and Cook.[116] According to their account, Aldermaston had not yet recovered from the stresses placed upon it from the HER programme and the Totem trials in 1954 as staff had been called to put in a tremendous and unsustainable effort to produce results.[117] This position is vindicated by Penney who wrote in May 1954 that even the though the exertions had been heavy, "the morale of the non-industrial staff in AWRE…[had been at a] very high level… during the "Hurricane" and "Totem" trials," but had since "steadily declined."[118]

In testing this hypothesis, this thesis disputes the cause, duration and solution to the 'crisis' of morale that persisted at AWRE. The following section will present the readily acknowledge contemporary perception that the transition to the UKAEA created a significant "fear of the unknown" amongst many staff as they now perceived themselves to be exposed to the "icy blasts" of working conditions within a nationalised corporation.[119] For example Penney noted in a May 1954 memo that three of the four "reasons for the drop in morale" were due to issues pertaining to the foundation of the UKAEA.[120] Arnold and Pyne credit the move to the UKAEA for creating "even more uncertainty and disruption" at Aldermaston but defer answering "whether the setting up of AEA at this stage was a wise, if difficult, measure to meet new circumstances and needs, or an untimely disruption at a critical period, is an interesting subject for discussion (but not here)."[121] As will be seen, the transition to the UKAEA significantly exacerbated difficulties in recruitment and retention

[116] Arnold and Pyne, (2001), p.76-79. They also quote John Corner (head of AWRE's theoretical Physics division) who believed that AWRE "was displaying classic symptoms of an approaching nervous breakdown." See p.76
[117] Ibid., p.76
[118] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954
[119] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954 & TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954
[120] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954. The fourth, that arms control was making future work uncertain was also exacerbated by the transition to the UKAEA – see 'Retention' section.
[121] Arnold and Pyne, (2001), p.75

of staff at a time where it was vital for AWRE to expand its strength. The following section will also make it clear that resolving the problem of morale in Aldermaston was both critical to the progression of the thermonuclear programme and that it involved a number of "expedients" and longer term policies.[122] AWRE's lingering inability to reach its full complement indicates that these problems persisted throughout the thermonuclear programme.[123] It will be argued that the promise of diversified work at the establishment was used to stabilise the morale at AWRE rather than the personal leadership of Penney or Cook. However, diversification was never satisfactorily delivered upon, which would have important future consequences for AWRE.

The UKAEA and Failure to Improve Retention

When Cherwell spearheaded the initiative to reform the UK's nuclear programme into the UKAEA, he did it on the basis that the scientific civil service had failed to deliver results promptly compared to Soviet Russia or the United States.[124] He believed that the transition to a nationalised corporation would allow for greater institutional freedom in resolving employment issues, thereby attracting more qualified individuals who would accelerate progress.[125] In practice, when AWRE was moved to the UKAEA in 1954, it generated problems of its own. The transition towards the UKAEA had the most profound effect on junior white paper grades at AWRE as their employment conditions had significantly changed, without those affected giving their approval to the move. As the shift to the UKAEA was a measure imposed on the former MoS scientists, staff were provided an 'option period' wherein they retained the right to swap back into the scientific civil service until February 1956.[126] This imposed further uncertainty on the Weapons Establishment as management was unsure of who would remain, and by extension, who would have to be recruited to fill vacated roles.[127] Understandably, Penney complained that "it is extremely difficult to plan the programme of the Establishment when we do not know how many of the present staff will leave."[128] It was therefore recognised by the UKAEA that "the greater need [than recruitment at mid and low levels] is to ensure continuity by keeping as many as possible of the existing staff, particularly the scientists,

[122] TNA, ES1/525, Penney to Plowden, 14/01/1955
[123] TNA, ES1/1503, Complement and Strength of Staff at Aldermaston, 24/12/1958
[124] Birkenhead, (1961), p.298
[125] Paget and Scott, (1958), p.66
[126] TNA, ES1/1421, Group Secretaries' Conference, 01/11/1955
[127] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954
[128] Ibid.,

engineers and technicians. To the extent we are unable to do so, then the greater our recruitment problems."[129]

However, rather than tangible differences between conditions in the scientific civil service and UKAEA, Penney noted that the subsequent crisis in morale was perhaps "more emotional than rational" due to a breakdown of trust between staff and senior administrators.[130] This meant that when some verbal assurances to the staff were made by the UKAEA that any negative consequences would be minimised, it appears that they were rejected due to the prevailing sense of mistrust between staff and the executive. [131] Whatever the reality of new conditions under the new UKAEA, staff disquiet with the situation was sufficient for Penney to believe in June 1954 "that a dangerous percentage of his staff might not accept Authority terms of employment."[132] Trust in the new authority was especially important for staff working at Fort Halstead or Woolwich Arsenal, as they were being asked to uproot themselves and their families to Aldermaston to unclear working conditions and questionable employment stability.[133] An additional and somewhat justified fear was that further changes to the conditions of staff at the UKAEA would be imposed upon them in the future, so protestations had to be made now to make it clear that this would be unacceptable.[134] The disgruntlement amongst certain sections of staff with the situation was such that Penney memoed Plowden in January 1955, stating that "the main threat to the "scientific", in contrast to the "political", success of the 1956 trials lies in the disaffection of the electronics teams at Fort Halstead."[135]

Perhaps the obvious solution would have been to increase salaries for all AWRE staff in compensation for any perceived loss in benefits for being removed from the civil service. Despite the immense resources that would be devoted to the thermonuclear programme, significant wage increases were not an acceptable solution to central government; inflation and wage spiralling were

[129] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954
[130] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954. Penney's characterisation.
[131] TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954
[132] TNA, AB41/514, AEX Minutes, 03/06/1954
[133] TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954, TNA, ES1/340, A Message to Sir William Penney From the IPCS Members at Fort Halstead, (n.d.) & TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955. While work was continuing to be progressively transferred from stations like Fort Halstead to Aldermaston with an eye on the termination of UKAEA work, outlying stations played a vital role in the thermonuclear programme. TNA, ES1/248, AWRE Fort Halstead Industrial Staff not transferring to Aldermaston, (n.d.) & TNA, ES1/340, Re: AWRE Industrial Appointments Fort Halstead, 12/02/1954
[134] TNA, ES1/340, A Message to Sir William Penney From the IPCS Members at Fort Halstead, (n.d.)
[135] TNA, ES1/525, Penney to Plowden, 14/01/1955

already damaging the UK economy and there was a push for wage "stabilisation."[136] As the transition to the UKAEA came with no appreciable increase in funding, any shifts in the levels of wages for particular grades was a zero sum game: an increase for senior staff meant a relative decrease for junior grades. The logic for this had been that the UKAEA's "most urgent problem…[was] to ensure the retention of… existing senior staff and to secure an adequate supply of high level staff from Industry and elsewhere" where they were paid comparatively more.[137] While this had the intended effect of retaining senior scientists within the UKAEA, it was a cause for disgruntlement amongst other junior ranks.[138] Due to the protestations of the remaining scientific civil service, a further constraint placed upon the UKAEA was that pay "in respect of all save top-level posts" was linked to that of the civil service, meaning that junior pay couldn't be increased even if there had been the will to do so.[139]

Transition to the UKAEA also undermined certain benefits that made a career in the scientific civil service attractive. Even when staff were offered an immediate salary increase of 7% for transferring to the UKAEA, it translated in real terms to a pay increase "of only about 0.6%" when factoring in the loss of generous pension contributions.[140] This was perceived as providing "derisory recompense for various disadvantageous features of employment under the Authority."[141] The effects of poor financial compensation were especially acute as the scientific civil service provided a great amount of flexibility for scientists who could transfer to different departments and research projects when there were open vacancies.[142]

Another protection offered by the scientific civil service was that it offered protection against "abolition of office," meaning "considerable efforts" would be made to find alternative work before "pensioning them off."[143] The lack of these two benefits led to concerns being expressed by AWRE staff who were considering transfer to the UKAEA of being left workless by future arms control treaties.[144] Penney noted at a meeting of the AEX in May 1954 that "The popular outcry for the banning of atomic and super weapons [was] resulting in a feeling of impermanence." [145] This observation was shared by the Lord President of the Council, who stated in September 1954 that

[136] TNA, AB16/1778, Lloyd to Brooking, 09/08/1954 & Jefferys, (1997), p.28
[137] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954
[138] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954 & TNA, ES1/343, United Kingdom Atomic Energy Authority, 01/11/1954
[139] TNA, ES1/343, Pay and Structure of the Atomic Energy Authority, 03/09/1954
[140] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954
[141] Ibid.,
[142] HM Government, (1945), p.280
[143] TNA, ES1/340, A Message to Sir William Penney From the IPCS Members at Fort Halstead, (n.d.)
[144] TNA, ES1/343, Careers in the Atomic Energy Authority, 07/11/1954
[145] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954

"staff are apprehensive that an international agreement banning or curtailing work on weapons would lead to redundancy."[146] A particular concern for certain staff at the Weapons Establishment was that their work was more similar to that conducted by the MoS in other armament projects.[147] From an individual's career perspective, it would be foolhardy to remain at AWRE rather than transfer back to the wider civil service, where there would be a greater chance of future work – a factor that was acknowledged and needed to be countered according to the UKAEA.[148] The outspoken Fort Halstead union representatives demanded that "some channel back to the Civil Service must be kept open."[149]

The UKAEA's initial attempt to assuage staff fears in 1954 was by stressing "redundancy is just about as likely as it was in the railway business a century ago" and that they could be found jobs within the rest of the UKAEA, given that Aldermaston's infrastructure would be useful for continued civil research.[150] While this implied a pledge of other employment in the authority, it appears that the concerned staff simply did not accept this as sufficient. [151] When reassuring statements failed, multiple initiatives were discussed as part of plans to further assuage these fears from mid-1954 to February 1956. These included approaching the MoS to attempt to obtain a commitment that if UKAEA staff were made redundant, particularly those from the weapons groups with speciality tacit knowledge based skills (now terming themselves "weaponeers"), they would be readmitted into the scientific civil service.[152] Rather than the MoS, it appears that this proposal seems to have been ultimately vetoed by the Treasury.[153] An alternative suggestion was that the UKAEA should offer the guarantee that all AWRE staff transferred over would have employment guaranteed until they were 60. This was proposed in the expectation that even in the case of nuclear disarmament, few would be unable to be transferred to alternative work. [154] Penney offered an alternative suggestion at an AEX meeting in June 1954 that the government should make "a policy statement from the Government as to its future use for atomic weapons [as it] would be helpful in allaying fears of the

[146] TNA, AB16/2303, Authority Whitley Council Meetings, 11/10/1954
[147] TNA, ES1/427, Waverley Committee – Responsibility for Atomic Weapons, 18/05/1953. This had also been the main arguments held out for why AWRE should have been retained within the MoS and the auspices of the scientific civil service.
[148] TNA, ES1/343, United Kingdom Atomic Energy Authority, 01/11/1954
[149] TNA, ES1/340, A Message to Sir William Penney From the IPCS Members at Fort Halstead, (n.d.). Scientific civil servants were represented by the Institution of Professional Civil Servants, a union founded in 1919. The branch at Fort Halstead proved the most vocal in the Weapons Group about the transition to the UKAEA.
[150] TNA, ES1/340, A Message to Sir William Penney From the IPCS Members at Fort Halstead, (n.d.)
[151] TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954
[152] Ibid.,
[153] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[154] TNA, AB16/1778, Donald Perrott to D.R. Willson, 09/07/1954

staff."[155] This is a clear example of an institutional interest attempting to influence the government's declaratory nuclear weapon policy to further its own interests.[156]

Other ideas discussed between mid-1954 and January 1955, but ultimately discounted, included offering a flat 10% pay increase or an upfront monetary award for those joining the UKAEA.[157] The AEX also considered seconding scientists directly from the MoS back into AWRE in the crucial run up to trials.[158] This was rejected by Penney due to the "discontentment" it would introduce to have some staff working in (rather than for) AWRE on scientific civil service conditions.[159] In the interim, a measure implemented to improve the retention of staff was to simply request that the MoS did not attempt to recruit staff from AWRE during their option period.[160] The final arrangement agreed before the option deadline passed in February 1956 with the Treasury was that any staff made redundant by the UKAEA would be "provide[d] the opportunity of return to the Civil Service if a suitable post can be made available."[161]

A concurrent process that further emphasised the importance of retention was a growing awareness amongst AWRE's workers of their own perceived embodied tacit knowledge. This hypothesis is evidenced by the emergence of the term 'weaponeers.' Although the term is present in the official history of this period, the account does not note this as a new development.[162] However, the primary sources explicitly note that the term 'weaponeer' emerged during industrial disputes between AWRE staff and the UKAEA administration. Select industrials with specialist nuclear weapons skills that did not have clear application in the civil sector began to self-identify as "weaponeers" to emphasis their value to the establishment based on their embodied experience.[163] This proved problematic in the transition to the UKAEA as "these "weaponeers" consider that they have a wider scope for their talents in the MoS research establishments than in the atomic energy authority."[164] This term was strongly contested however as it was perceived by its detractors as being used to leverage special privileges (either increased pay or stronger guarantees of continuing

[155] TNA, AB41/514, AEX Minutes, 03/06/1954
[156] Ibid.,
[157] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955 & TNA, ES1/343, Brooking to Shirlaw & Willson, 06/08/1954
[158] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[159] Ibid.,
[160] TNA, AB16/1230, Peirson to Elwell, 23/10/1954
[161] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[162] Arnold and Pyne, (2001), p.xiii
[163] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954.
[164] TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954

employment) for AWRE workers that were denied to other UKAEA staff.[165] For example, a July 1954 memo by Perrott reports that a non-AWRE UKAEA staff member "represented very strongly" that the case of the "weaponeers" was overblown and that they were "by no means so much of a specialist as had been argued."[166] The "discrimination in favour of AWRE" was apparently generating significant resentment from the rest of the UKAEA staff, which is unsurprising given that serious consideration was being given to a flat 10% pay raise for AWRE non-industrials above the rest of other UKAEA departments.[167] Even if disputed, the first clear claim to tacit knowledge made by AWRE staff stemmed from the interlinked processes of the high work load of the thermonuclear programme and the morale 'crisis' under the UKAEA. Although based in temporal circumstances of AWRE in the 1950s, satisfying the 'weaponeers' belief in the longevity of their profession proved a long standing and pernicious issue.

Recruitment: Struggling to Expand

In July 1954, discussions in cabinet optimistically proposed that "if further scientists could be recruited, this additional production [of hydrogen bombs] could be undertaken without serious disruption of [the] existing programme for the manufacture of atomic weapons."[168] Therefore, even disregarding replacing the losses from staff who stayed within the civil service, the feasibility of the hydrogen bomb programme was predicated on significantly expanding staffing levels at AWRE.[169] However, this proposal seemed to diverge from the reality of recruitment for Aldermaston. During the HER programme, AWRE's recruitment of scientists had been a perpetual problem and this had remained unresolved by the end of 1953: a 16th December meeting noted that "despite intensive

[165] Such as those at Capenhurst or Harwell.
[166] TNA, AB16/1778, Donald Perrott to D.R. Willson, 09/07/1954. Even at the time, 'Gillieson' argued that "his [a weaponeer's] basic scientific training had equipped him so that he could turn over to some quite different field of work within only a short period."
[167] TNA, AB16/1778, Donald Perrott to D.R. Willson, 09/07/1954 & TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954. Penney later favoured diversification over pay increases. Hinton also strongly protested increasing AWRE wages when Research group staff would receive no equivalent compensation. See TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[168] TNA, CAB128/27, Cabinet Conclusions, 07/07/1954
[169] Recruitment for the thermonuclear programme was also essential in providing skillsets that AWRE had not previously had access to (or necessarily needed): until the announcement of the recruitment of Dr. Allen in September 1954, "Aldermaston had suffered… in having no nuclear physicists on the staff." See TNA, AB41/514, AEX Minutes, 14/09/1954

recruitment efforts… [Penney's] strength was still some 70 or so short of the ceiling of [the] 510 [complement] required."[170]

If recruitment of staff for Aldermaston had always been difficult, then the transition to the UKAEA was perceived to have made the task even harder. In late May 1954, Penney complained that there had been a "drop in morale, partly associated with the transfer to AEA, [and that it] should come at a time when large additions to the already crushing programme of the Establishment are being contemplated… it [is] quite clear that AWRE cannot meet a big addition to its programme without more staff."[171] This 'drop in morale' also meant to Penney that "we shall… certainly continue to have the greatest difficulty in recruiting new staff."[172] In November 1954, Donald Perrott noted that the strength for scientific staff at Aldermaston had only increased by 2% that year "despite sustained efforts."[173] This situation was clearly not compatible with prompt delivery of devices for thermonuclear tests.[174] In January 1955, Penney acknowledged the reality that the intended expansion of strength for white paper grades "from 507 to 668" (a 32% increase) for AWRE "would get nowhere near this target unless a real inducement was added."[175] It should also be noted that Penney acknowledged in a May 1954 report that continual recruitment was the reality for Aldermaston where staff wastage was "10% per year [even] before the drop in morale."[176] In October 1954, an AWRE official messaged the MoS acknowledging that "it is proving difficult to keep pace with wastage, let alone to build up the increased staff necessary if it is to meet its programme."[177]

In terms of the underlying issues with recruitment, many of the same problems that had inhibited recruitment during the HER programme continued to restrict AWRE's ability from 1954 onwards. Notable among these was the UKAEA's inability to substantially diverge from established Ministry of Labour or civil service pay rates (except at the most senior levels).[178] This was combined

[170] TNA, ES1/339, Notes of a Meeting held at Sir Christopher Hinton's House and subsequently at Risley Headquarters, 16/12/1953 & 17/12/1953. Recruitment in 1953 was complicated by the soon to be implemented transition to the UKAEA – new recruits in 1953 would be under civil service provisions, which would incur the same process and cost of transitioning them over to the UKAEA as longer-term members of staff.
[171] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954. AWRE staff had already nearly doubled between April 1952 and April 1954, going from 2306 to 3816. See TNA, AB16/1778, Appendix A to Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954
[172] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954
[173] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954
[174] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954
[175] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[176] TNA, AB16/1230, Atomic Energy Executive – Special Measures for AWRE by Sir William Penney, 27/05/1954
[177] TNA, ES1/343, Peirson to Lindsell, 23/10/1954
[178] TNA, AB16/1778, Penney to Lloyd, 22/03/1954

with what Cherwell recognised as "a genuine dislike of AWRE work, both on account of its intrinsic [dangerous] character and of the secrecy."[179] When these factors were combined with the perceived impermanence of the UKAEA, it is unsurprising that Aldermaston faced recruitment issues.[180]

Dealing with wastage, meagre recruitment and the need to rapidly expand left Aldermaston with a problem across most grades, both for industrial and non-industrial employment. This was recognised as an issue in February 1955 when rather than scientists, "one of the limiting factors in the balanced growth of Aldermaston may lie in the local scarcity of unskilled… industrials."[181] For example, as with during the HER programme, national shortages of draughtsmen meant "service rates do not enable us [AWRE] to recruit and retain sufficient basic grade draughtsmen in competition with private industry."[182] One of the key problems in obtaining labour was that local contractor rates were several pence higher per hour.[183] Lack of labour was reportedly having serious implications for the progress of work: the Chief Engineer reported in July 1954 that although he had "ample facilities," work was being delayed due to a lack of manpower which "he could employ almost immediately."[184] Such issues were partially alleviated by offering "X" rates of pay: the band offered for dangerous work involving "chemical and/or explosive work."[185] Although this didn't entirely close the pay gap between AWRE and the wider private sector, other incentives, such as subsidised housing and a wider work portfolio helped to mitigate the issue. [186]

Social Solutions for Technical Results

Offering Additional Housing

If AWRE was to deliver results from the thermonuclear programme before halted by a test ban, improving staff recruitment and retention was essential. Not only was an expanded workforce

[179] TNA, AB16/1230, Lord Cherwell to Duncan Sandys, 15/09/1953
[180] TNA, AB16/1230, Donald Perrott to B.D. Fraser, 01/11/1954
[181] TNA, ES1/920, Recruitment of Unskilled Industrials at AWRE, 18/02/1955
[182] TNA, ES1/343, Palliatives to Assist Recruitment, (n.d.). Other industrial grades in critical demand at Aldermaston included jig borers, inspectors, optical glass workers and electronic testers. These grades were "extremely difficult class[es] of labour to obtain as industry pays far higher wages than we [AWRE] are able to offer." See AB16/1778, Reference: W4/CE.8-6 by JRV Dolphin, 20/06/1954.
[183] TNA, AB16/1778, Penney to Lloyd, 22/03/1954
[184] TNA, ES1/920, Stone to V.D./AWRE, 13/07/1954 & TNA, ES1/920, Labour Allocation, 04/02/1955
[185] TNA, AB16/1778, Meeting held at Aldermaston to Discuss Incentives to be Offered to Weapons Group Staff, 14/06/1954
[186] TNA, AB16/1778, Lloyd to Brooking, 09/08/1954, TNA, AB16/1778, Hatchett to Beecham, 30/06/1959, TNA, AB16/1778, Penney to Lloyd, 22/03/1954 & TNA, AB16/1778, Note – Lloyd, 01/09/1954

necessary, but it needed to keep its current skilled staff to train the incoming cohort. As during the fission programme, the most immediately available solution was increasing the amount of housing available to be offered to staff. As Arnold and Pyne note, a significant attraction of joining AWRE's staff as a married man was that it "offered the added advantage of a house, at a time when housing was scarce."[187] Single men and lower grades were offered either lodging allowances or hostel accommodation.[188] AWRE's "first and major commitment in so far as housing is concerned" was providing for staff expected to move to Aldermaston from Fort Halstead or Woolwich Arsenal. [189] As many of the staff being transferred were still in their option period, being able to offer housing promptly was a practical necessity if they were to be retained. Building housing also allowed AWRE to attract more workers into the area, which was proving necessary "as we [AWRE] exhaust still further the resources of local recruitment." [190] While pay from AWRE struggled to be competitive with the private sector for many grades (even with "X" rates), being able to offer housing was seen as a sufficient lure to offset this disadvantage and enable national recruitment campaigns.[191] Even as housing supply improved after WW2, offering subsidised housing was still vital to offset the allure of the buoyant employment market in London.[192] As a result, although 350 houses had been built and occupied by AWRE by 1955, a further 400 were under construction and another 400 were planned and awaiting approval.[193] Although the approved ceiling for new house construction was set at 1500, AWRE pushed for this to be raised to 1900 in February 1955 to accommodate the increasing staff levels now required by the thermonuclear programme.[194]

The problem became that the need to provide housing became ever more acute as Aldermaston needed to expand in order to deliver for the Grapple tests.[195] As local labour became insufficient to fulfil AWRE's needs, more unskilled labour had to be 'imported' into the area, which

[187] Arnold and Pyne, (2001), p.82
[188] TNA, AB16/1430, Amenities and Facilities at Aldermaston – Report by Sir Donald Perrott and Sir William Penney, (n.d.)
[189] TNA, ES1/920, Recruitment of Unskilled Industrials at AWRE, 18/02/1955 & TNA, AB16/1429, Aldermaston – Future Housing Requirements, 24/03/1954. Housing for transferred staff was provided within 3 months. See TNA, ES1/278, Brooking to Perrott, 17/05/1954
[190] TNA, AB16/1429, Aldermaston – Future Housing Requirements, 24/03/1954 & TNA, AB16/1429, Aldermaston Housing Programme, 22/02/1955 - "43% of their [AWRE's] non-Industrial and skilled Industrial staff, 6% of their unskilled Industrials and almost all their Constabulary" were expected to take up the offer of UKAEA authority housing. TNA, ES1/279, Copy of Minute form WM Hill to the Chairman, (n.d.)
[191] TNA, ES1/920, Recruitment of Unskilled Industrials at AWRE, 18/02/1955
[192] TNA, AB16/1429, Aldermaston – Future Housing Requirements, 24/03/1954
[193] TNA, AB16/1430, Amenities and Facilities at Aldermaston – Report by Sir Donald Perrott and Sir William Penney, (n.d.)
[194] TNA, AB16/1429, Aldermaston Housing Programme, 22/02/1955. 1920 houses had been "built or acquired" by 9th November 1956 for AWRE. TNA, AB16/1429, Aldermaston Housing 1957/8, 09/11/1956
[195] TNA, AB16/1429, Aldermaston Housing 1957/8, 09/11/1956

placed further demands on housing.[196] In addition hostels proved an unsatisfactory long term solution for single men as higher grade staff demanded flats instead.[197] In turn it was recognised by 1957 that the building work itself (both of flats, amenities, houses and facilities in Aldermaston) was becoming self-perpetuating as contractors had to house "their imported employees" while the Aldermaston site continued to expand.[198] This was an issue that AWRE never adequately solved as the problem expanded and waiting times remained considerable.[199] For example, in 1958, the waiting time for housing was 12-15 months so there was consideration put towards "restricting houses to scarcity classes" only.[200]

Although clearly a continuing cause for concern during this period, housing never appears to have become so acute as to entirely threaten recruitment. Nevertheless, at certain periods, lack of housing appears to have been the limiting factor to Aldermaston's expansion and thereby progression to the Grapple tests. For example, a letter from Admiral Brooking to Donald Perrot complained that the "lengthy wait [9 months] is having a most unfortunate effect on our recruitment programme and moreover we are losing a steady drain of skilled men who cannot afford to maintain their families elsewhere."[201] In the end, "the housing programme at Aldermaston…[which progressed at] high speed" was eventually judged to provide sufficient authority housing, even if there was an extended waiting period.[202] Nevertheless, the provision of housing posed considerable managerial demands upon AWRE as they were tasked with supporting the community that they had fostered. In practical terms, this meant provisioning schools, shops, churches, transport, medical services, etc. for the housing estates serving Aldermaston.[203] As this had to be subsidised with public money, the Treasury sometimes proved a reluctant partner in the endeavour, with prevarications on approving spending meaning "valuable months were lost at the close of 1953" in building housing stock.[204] AWRE also received little support from local authorities. Their disassociation from AWRE's community building was "aggravated by the fact that the County boundary goes through our housing area," resulting in neither taking direction over the situation.[205]

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[196] TNA, AB16/1429, Aldermaston Housing Programme, 22/02/1955
[197] TNA, AB16/1430, Amenities and Facilities at Aldermaston – Report by Sir Donald Perrott and Sir William Penney, (n.d.)
[198] TNA, ES1/279, Plowden to Mr Freeth M.P., 04/01/1957
[199] Ibid., On 4th Jan 1957, Plowden complained that housing 'imported' labour was "no less pressing today" compared to 1955.
[200] TNA, ES1/1503, House Purchase Incentive Scheme, 12/1958. In 1956, housing was offered on the basis that if would be provided within 12 months. TNA, AB16/1429, Aldermaston Housing 1957/8, 09/11/1956
[201] TNA, ES1/278, Brooking to Perrott, 17/05/1954
[202] TNA, ES1/279, Copy of Minute form WM Hill to the Chairman, (n.d.)
[203] TNA, AB16/1430, Amenities and Facilities at Aldermaston – Report by Sir Donald Perrott and Sir William Penney, (n.d.) & TNA, AB16/1430, Notes on Amenities, (n.d.)
[204] ES1/278, Brooking to Perrott, 17/05/1954
[205] TNA, AB16/1430, Cross to Parking, 20/05/1957

Given housing's importance to recruitment (and the capacity that it drew from AWRE's senior management), it is perhaps surprising the lack of help provided by either central or local government in coordinating the local community that emerged to support AWRE.[206]

Conditions During Testing

The other area in which accommodation was an issue was for maintaining staff morale at the nuclear test sites in the South Pacific. Cook complained on 16th October 1957 "that the treatment at Christmas Island of the 30-40 junior AWRE staff was so bad as to jeopardise future trials."[207] Poor conditions included flu outbreaks, dysentery, swarms of flies, crabs, rats and ants, torrential rain, flooding and tropical heat on men kept in tents.[208] Nevertheless, funding was not forthcoming for more permanent housing structures to improve conditions.[209] After the Grapple X test in November 1957, an AWRE paper complained that "the health of the personnel who will have to stay on Christmas Island alone demands better accommodation than tentage."[210] It was noted that "accommodation for civilians at Christmas Island during the November operation had been poor and the AWRE would not be able to obtain the necessary staff for the March [1958] operation unless an improvement was made."[211] While AWRE wanted to improve conditions for its staff as a matter of priority, it was realised that this would be impractical unless conditions for the servicemen on the island also improved.[212] More money was committed in late 1957 for improvements but the continuing poor conditions on Christmas Island led to two debates in Parliament in early 1958, which further highlighted the issue to the public.[213] According to Arnold and Pyne, the new money committed in 1957 only covered "minimum repairs and improvements"; a request for an $800 ice

[206] It is notable that Penney and Donald Perrott were having to direct the creation and provide details of the necessary "amenities and facilities at Aldermaston," rather than being able to delegate the issue. TNA, AB16/1430, Amenities and Facilities at Aldermaston – Report by Sir Donald Perrott and Sir William Penney, (n.d.)
[207] TNA, AVIA65/1431, US/SAW to AS/AW, (n.d). This also contrasts with Arnold and Pyne's account that asserts a "common effort and absolute commitment" that allowed AWRE staff to continue working poor conditions. Arnold and Pyne, (2001), p.82
[208] Arnold and Pyne, (2001), p.147 & HC Deb 14 February 1958 vol. 582 cc819-28
[209] TNA, DEFE7/921, Macklen to Powell – Nuclear Test Policy Committee, 18/11/1957. Estimated at a cost "of at least £2 million." TNA, DEFE7/922, Cabinet Nuclear Tests Policy Committee – Future Trials at Maralinga, 14/11/1957
[210] TNA, DEFE7/922, Further Information on Proposals for Megaton Tests – E171, (n.d.)
[211] TNA, DEFE7/922, Cabinet Nuclear Tests Policy Committee – Future Trials at Maralinga, 14/11/1957
[212] Ibid.,
[213] HC Deb 29 January 1958 vol. 581 cc345-6 & HC Deb 14 February 1958 vol. 582 cc819-28

machine to combat tropical heat "was ruled out by Whitehall as too expensive."[214] Although not enough to halt tests, the true reprieve for those serving (either in the forces or with AWRE) was the halt to British nuclear atmospheric testing in the South Pacific in 1958.[215]

Role of William Cook: Improved Management?

As highlighted as one of the hypotheses to be tested in this chapter, a factor highlighted by Arnold and Pyne in allowing AWRE to recover from its 'crisis' of morale in 1953 was William Cook's co-leadership with William Penney.[216] This section will therefore attempt to provide an assessment of Cook's contribution as Deputy Director of AWRE during the thermonuclear programme. With the limited available archival material on the issue, it will find that rather than instituting a cultural change to British nuclear weapons development, Cook's greatest contribution at AWRE was acting as a stabilising managerial influence when it was most needed for the programme.

Cook's established prowess as a scientific administrator was well known to Penney even before Cook joined the AWRE in September 1954. Penney had already attempted to recruit Cook as Aldermaston's deputy in 1950, but this request had been bluntly refused by the Admiralty, from whom "he could not be spared."[217] Instead, Vice-Admiral Patrick Brooking was employed as Penney's assistant, but was a "complement to Penney, rather than a substitute."[218] However, with the thermonuclear programme looming in late 1953-1954, the issue of appointing a Deputy Director "to share the load with Penney" returned to prominence.[219] Contrary to Cook's Royal Society biography and Arnold and Pyne's official history, Oikonomou notes that it is unclear from the available archival material whether Penney willingly accepted that he needed a deputy at all at least by the end of 1953.[220] Even if Penney did acknowledge his need for a deputy, Cook was only one of several (and potentially third choice) potential candidates to fill the role.[221]

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[214] Arnold and Pyne, (2001), p.169
[215] Ibid., p.219. Minor trials (permitted under the testing moratorium) continued at Maralinga until 1967.
[216] Ibid., p.78 & p.81-82
[217] Cathcart, (1994), 264.8/673
[218] Ibid., 264.8/673. Brooking's role was changed after the appointment of Cook to liaise with Whitehall and the Chiefs of Staff. TNA, AB41/514, Items 2, 3 and 4 of AEX 11th Meeting, 17/06/1954
[219] Penney and Macklen, (1987), p.50
[220] Oikonomou, (2011), p.121, Arnold and Pyne, (2001), p.77 & Penney and Macklen, (1987), p.49
[221] Arnold and Pyne, (2001), p.77

Despite Penney's potential misgivings about anyone's ability to fulfil the role of his deputy, Cook is given credit by multiple secondary sources for his work between 1954-1958 in reforming Aldermaston's management and his personal contributions to the successful outcome of the thermonuclear project. [222] For instance, according to Arnold and Pyne, Cook's main contributions to Aldermaston that enabled the successful completion of the bomb programme was instigating a cultural "transformation."[223] Prior to Cook, Arnold and Pyne suggest that a combination of security measures, the physical geography of the Aldermaston site and Penney's style of personally overseeing many technical aspects meant that information became heavily compartmentalised and withheld on the "need to know principle."[224] They further add that Penney withheld information from fellow scientists as "he thought…[the data] too secret to share or because he did not realize their value to them."[225] This reportedly changed with Cook's foundation of the Weapon Development Policy Committee in April 1956 which is claimed to have greatly assisted information sharing.[226]

As Oikonomou observes, verifying Cook's contributions and impact from 1954-1958 is challenging as files pertaining to many technical developments of AWRE's work remain classified.[227] Given the paucity of information, it would be difficult to challenge the weight of secondary material that praises Cook's role, but some further comments are possible based on the available archival material. Regarding information sharing at Aldermaston, while the Weapon Development Policy Committee may have solved the problem for senior scientists, issues clearly remained. Charlie Martin, an Aldermaston scientists chiefly concerned with developing initiators wrote in November 1959 that junior white paper grades still retained "only… the vaguest knowledge" of general weapons design concepts.[228] This was reportedly due to the continuing strict application of the 'need to know' principle implemented after the "extensive security clamp down" after 1947; presumably as a result of the espionage activities of Fuchs and Maclean.[229] This culture of secrecy apparently

[222] Arnold and Pyne, (2001), p.78 & 81-82, Penney and Macklen, (1987), p.50-52, Oikonomou, (2011), p.120-122. Makins, (1994), p.293. Penney took up leadership for Harwell in July 1959, so was less present before his official replacement in AWRE by Claude Pelly in 1960.
[223] Arnold and Pyne, (2001), p.59 & p.81
[224] Ibid., p.80
[225] Ibid., p.81
[226] Ibid., p.81
[227] Oikonomou, (2011), p.121
[228] Fishlock, (1999) & TNA, ES1/1323, The Problem of Dissemination of Secret and Top Secret Information Amongst Junior Scientific Staff, 18/11/1959
[229] TNA, ES1/1323, The Problem of Dissemination of Secret and Top Secret Information Amongst Junior Scientific Staff, 18/11/1959

starkly contrasted with Martin's experience at the US Laurence laboratories, where young scientific grades were familiar with "the current [sic] ideas" on weapons design.[230]

This sentiment for the need for nuclear weapons education for young scientists was shared with A.R. Bryant who further stated that the "most valuable thing the "old hands" can do at the present stage is to make sure that the new generation can in fact stand on their shoulders."[231] The solution proposed, that was accepted by Claude Pelley, was for a lecture and fast track training scheme for junior scientists to educate them on the history of weapons design. [232] Therefore it is clear that although Cook may have contributed to information sharing at a senior level, cultural problems remained, based on the 'need to know' principle at Aldermaston. The ongoing effect of the presiding culture was perceived to be significant enough as worth highlighting and reforming after 1958. As will be seen in the next chapter, the perceived need to retain the elite senior scientists who were reportedly vital to sustain the viability of the establishment would dictate AWRE's push for further nuclear work in the 1960s. Had junior scientists more freely enjoyed in the accumulation of knowledge and experience accrued in this period of high activity for AWRE, it is open to speculation whether AWRE would have asserted its ongoing fragility in the 1960s.

While the above challenges Cook's ability to entirely reform Aldermaston's culture during his tenure as Deputy Director, other pieces of archival material attest to the importance of his organisational skills. In a note to the Prime Minister dated 16th April 1958, Plowden details how the UKAEA had been "forced" to move Cook "to the Industrial group of the authority."[233] This came shortly after the Windscale fire in 1957 and as Oikonomou states, was presumably due to the need for "a strong managerial hand to head the Authority's Industrial side, following…[Britain's] first nuclear accident."[234] If that were not evidence enough for the UKAEA's faith in Cook, the memo states how Cook's services were partially seconded back to the Weapons Group to speed up the Grapple Z series of tests. In an April 1958 memo to the Prime Minister, it is conveyed that by "re-arranging" and "dropping" some work, in combination "with the additional help…[Penney] now can get from Sir William Cook," the test time table could be moved forward by two months.[235] The essential role of Cook was restated in Atomic Weapons Trials Executive meeting minutes where it is noted that "to assist in this acceleration Sir William Cook had been loaned to AWRE from the AEA

[230] Ibid.,
[231] TNA, ES1/1323, Problem of the "Need to Know" Principle, 26/11/1959
[232] TNA, ES1/1323, The Problem of Dissemination of Secret and Top Secret Information Amongst Junior Scientific Staff, 18/11/1959 & TNA, ES15/5, AWRE Management Committee Minutes, 23/03/1958
[233] TNA, DEFE7/923, Plowden to Prime Minister, 16/04/1958
[234] Oikonomou, (2011), p.123
[235] TNA, DEFE7/923, Plowden to Prime Minister, 16/04/1958

headquarters."[236] Having a competent deputy was especially important during the thermonuclear tests, as Cook's physical presence in the South Pacific allowed authoritative decisions to be made on site.[237]

Therefore, it is reasonable to conclude from the available archival information that Penney and the UKAEA relied on Cook to act as the Authority's managerial 'firefighter.' While the specifics of his actions and measures remain unclear beyond what is provided in the official history, this supplementary evidence lends credence to his organisational abilities. Cook's ability to deploy his reportedly "logical step by step method and… [refusal] to be panicked into a more pragmatic approach" could also not have come at a better time for AWRE.[238] This became progressively more important as Arnold and Pyne note that after the failure of the first Grapple series, "Cook took a more personal grip on the H-bomb work as Penney took less part in it."[239] His success in driving AWRE progress forward from 1957-1958 with the looming pressure of a test ban likely merits the praise he received from his contemporaries, summed up by McIntyre who states that "the general feeling at AWRE was that the H-bomb could not have been achieved without Cook's direction."[240]

Diversification: Technical Solutions to Social Problems

While providing housing and temporary pay increases was a method to attract staff in the short term, "the long term [solution]… to his [Penney's] staffing problems" was to provide a diversified work portfolio for AWRE.[241] Diversification meant transferring non-weapons work (from other UKAEA establishments or creating new work entirely) to AWRE: this less secretive work would potentially be less classified, possibly allowing AWRE scientists to publish for peer review and have less onerous security measures placed upon them.[242] Diversification was explicitly linked with its intended "morale effect on staff and to ease the switch from weapons if such a change is ever required" as a result of an arms control treaty.[243] It was also recognised that there may be a limited amount of work in the future: resolution of "the important developments being completed within 3 -

[236] TNA, DEFE7/923, Atomic Weapons Trials Executive – Operation Grapple, 17/04/1958
[237] TNA, AB16/2439, William Penney to Edwin Plowden, 13/05/1957
[238] Arnold and Pyne, (2001), p.154-155
[239] Ibid., p.152
[240] McIntyre, (2006), p.33
[241] TNA, AB41/588, Top Secret Annex to AEX 5th Meeting, 12/03/1955
[242] TNA, AB41/588, AEX Minutes, 27/01/1955 & AB16/1230, Extract from AEA 6th Meeting, 18/11/1954. Although new work preferably assigned to AWRE would presumably come at the expense of Harwell.
[243] TNA, ES1/525, Diversification at Aldermaston, (n.d.)

4 years" were hypothesised as being able to prevent AWRE from continuing "with a character of its own."[244] As a potential solution to the aforementioned crisis in morale that had been lingering since the transition to the UKAEA, Penney became convinced that diversification was the solution from late 1954 onwards.[245] Following an AEX meeting held on the 13th January 1955 which agreed on diversifying AWRE's research, Penney proclaimed that this "policy will have far reaching consequences."[246] Penney believed that "the broadening of the work in AWRE will gradually improve recruitment, will lower losses and may swing some present staff who intend to re-join the civil service into the AEA."[247] Such was Penney's belief that diversification was the answer to the morale problem at Aldermaston that he preferred pursuing that course of action even at the expense of pay increases. [248]

Rather than immediately providing an alternative stream of work, diversification was initially more of an effort to reassure staff, rather than provide a true alternative to weapons work. As envisaged by Penney in early 1955, only "a proportion of 10% on work outside the secret weapons field would be a reasonable aim."[249] This was projected at around "50-60" scientists being "allocated to this work."[250] Given the burden of work already imposed upon AWRE by the thermonuclear programme, this is unsurprising as few staff could be spared. Nevertheless, any diversion of staff away from their core work was seen as problematic and "might affect the programme."[251] This remained the case in the run up to Grapple; Cook acknowledged on 5th December 1956 that there was "very little allowance" for diverting staff towards a diversified research programme.[252] Nevertheless, "the Executive recognised… in the long run the balance of advantage clearly lay with the agreed policy [of diversification]."[253]

Penney's first preference for the work that Aldermaston would take on was for a British designed naval reactor.[254] In a letter dated 8th March 1955, Penney expressed Aldermaston's need

[244] TNA, ES1/525, Diversification Policy at Aldermaston, (n.d.)
[245] AB16/1230, Extract from AEA 6th Meeting, 18/11/1954. The first suggestion of Penney for diversification for AWRE at the AEX found was in a meeting held on 18th November 1954. Cherwell was receptive to the idea but suggested instead that staff should work part time at Aldermaston and part time on non-secret work at Oxford.
[246] TNA, ES1/525, Penney to Plowden, 14/01/1955
[247] Ibid.,
[248] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955 & AB16/1230, Widening the Scope of Aldermaston by Sir William Penney, 03/02/1955. Likely as a concession to Harwell – AWRE could either have preferential pay or a portion of Harwell's research, but not both.
[249] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[250] TNA, ES1/525, Penney to Plowden, 14/01/1955
[251] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[252] TNA, ES1/243, AWRE Compliment, 05/12/1956
[253] AB16/1230, Widening the Scope of Aldermaston by Sir William Penney, 03/02/1955
[254] TNA, ES1/525, Penney to Cockcroft, 08/03/1955

for the work, despite "the severe load in addition to the very high priority weapons work."[255] Military related work was preferable as "we feel that Aldermaston should be the Services establishment."[256] However, despite attempting to use Cook's naval connections to secure the programme, by 16th May 1955, Penney was forced to concede that AWRE was unable to develop naval reactors unless a delay in delivery was acceptable.[257] The Admiralty could not accept this as they viewed the programme as "urgent": the US already had their first nuclear powered submarine conducting tests and the Soviets were not far behind.[258] Several years had already been lost by Harwell insisting on their favoured gas cooled reactor solution.[259] While leaving the decision up to the UKAEA, the Admiralty expressed their "misgivings" in giving the project to the AWRE, fearful of further delays. This appears to have prompted Plowden into "re-examining the whole question," eventually leaving the project with Harwell.[260]

With naval reactors effectively removed as an option, the alternative project was for AWRE to develop small 'package' reactors for army and air force use.[261] Unfortunately, low demand resulting from an unclear use case kept the idea in a suspended state: not progressing, but not being cancelled either. This indecisiveness with the potential programme was expressed in 1955 with both "the specification for this reactor together with operational restrictions on design… not yet [being] clear."[262] As no operational requirements were forthcoming by April 1956, Penney complained that "so far there had been no clear indication of what the reactor was wanted for."[263] Nevertheless, AWRE completed a preliminary study in August 1956 for the MoD looking at various costs associated with the potential programme for a rocket, aircraft and army reactor, estimating it would cost £10 million over five years and employ up to 200 staff by 1962.[264] However, getting a financial

[255] Ibid.,
[256] Ibid.,
[257] TNA, ES1/525, Cockcroft to Penney 21/02/1955, TNA, ES1/525, Penney to Cockcroft, 08/03/1955 & TNA, ES1/525, Diversification of Aldermaston Meeting, 16/05/1955
[258] TNA, ES1/525, Diversification at Aldermaston, (n.d.)
[259] Hennessy and Jinks, (2015), 358.2/2011
[260] TNA, ES1/525, Diversification of Aldermaston Meeting, 16/05/1955
[261] Penney wanted AWRE's "ultimate objective" to be work on fusion reactors. See TNA, ES1/525, Diversification at Aldermaston, (n.d.). The ZETA reactors at Harwell initially showed promise but these results turned out to be false positives. Nevertheless, even when imminent fusion breakthroughs appeared imminent, the AEX agreed that "the general view of the Meeting was that… [fusion] work should not go to Aldermaston, even though the long-term future of Aldermaston remained uncertain." TNA, AB41/658, AEX: Authority Establishments - Location of Controlled Thermonuclear Work, 28/11/1958. Aldermaston had previously been working on small fusion reactors (with up to "20 to 30 on this work") but they were used to run weapons relevant thermonuclear experiments. TNA, AB41/588, AEX Item 3 Minutes – Fusion Reactors, 19/05/1955
[262] TNA, ES1/525, Notes of a discussion with Mr. Sargeaunt, SA to AC, 04/03/1955
[263] TNA, AB16/1910, To be taken at Executive as arising from the Strath Report, 03/04/1956 & TNA, AB41/664, AEX Minutes, 05/04/1956
[264] TNA, AB16/1910, Penney to Powell, 13/08/1956

commitment by the services or establishing a firm need for such a reactor remained elusive, prompting Penney to write to Plowden in April 1958 of the need to have some reactor work or otherwise face "steadily decreasing morale and an increasing rate of loss of staff."[265] Although not fully realised in this period, diversification was an initial foray in attempting to resolve what Penney clearly realised would be a perennial problem at AWRE. The supply of nuclear weapons work alone would not be consistent over time and therefore a way of providing additional research programmes was required.

The Cycle Resets: AWRE's Second Morale Crisis

Even though diversification was held as the solution to AWRE's long term stability as an institution, what work this would compose of and when it would be provided were questions that were continually deferred. This became ever more pressing when in the midst of Grapple Y being concluded successfully and hasty preparations being made for Grapple Z before the test ban, the Macmillan government was able to reach agreement on the US–UK Mutual Defence Agreement by July 1958.[266] Under the agreement, technical cooperation on nuclear weapons was encouraged between the two countries. As strengthening UK-US cooperation had been an objective of Conservative Party nuclear weapons policy, Harold Macmillan hailed the end of the McMahon act as "the great prize."[267] While Macmillan wrote a letter to Plowden crediting the American's new found willingness to cooperate due to the progress made by Aldermaston, such cooperation would inevitably come at the expense of AWRE's independent research and development efforts.[268] Even as the agreement was being approved in July 1958, Penney was writing to Plowden that "the US/UK Bilateral Agreement and a possible international agreement to suspend trials, may well cause us to reverse our direction [of expanding AWRE], and begin a rundown of staff."[269] Due to the greater maturity of American weapon designs, it was decided between September and October 1958 that AWRE would produce an anglicised version of the American Mark 28 warhead (rather than any of the indigenously developed thermonuclear Grapple devices).[270] The immediate need for further

[265] TNA, AB16/3362, Penney to Powell, 18/06/1958
[266] Unfortunately, the stages leading to the agreement are beyond the scope of this thesis but are covered by Walker, (2010)
[267] Macmillan, (1971), p.323
[268] Ibid., p.564-564
[269] TNA, AB16/3362, Penney to Powell, 18/06/1958
[270] Arnold and Pyne, (2001), p.208-209 & p.212-215

nuclear tests or plans to develop an indigenous 500lb warhead were therefore rendered moot.[271] In terms of reassuring the staff, Penney issued a statement transmitted across the AWRE that guaranteed that "steps will be taken by the Atomic Energy Authority to make full use of our staff and the magnificent facilities which we possess. There is a vast amount of work to be done over a wide field in the Authority's Civil Programme."[272]

The Treasury had hoped to make quick savings at AWRE by reducing the work force as the establishment's requirements for research would be lessened as they would now be producing copies of American designs.[273] This was not the case as recreating localised versions of American weapons proved challenging: according to the official history, variations in materials and measuring standards had to be resolved to overcome the "extremely small variations…[which] could have significant effects on a product as unforgiving as a nuclear weapon."[274] Moore highlights how a less sensitive explosive was used in British variants due to differing risk tolerances.[275] The role of interpersonal exchange in the transmission of tacit knowledge is highlighted by how many outstanding production issues were only resolved with the initiation of "stock-take" Joint Working Groups (JOWOGs) meetings between American and British weaponeers, that started in April 1959 and have continued to the present.[276]

The effort by the Treasury to reduce staffing at Aldermaston due to the receipt of American information was averted by a swift lobbying effort by Plowden and Penney in November 1958.[277] Plowden stressed that although American knowledge took Britain "as far as we need go along the nuclear weapons road," the agreement "imposes upon us a moral obligation to pursue further research."[278] As a result, AWRE was saved from an immediate cut and instead received a further £10 million for research; as Penney had argued, "the logical consequence is that we must have in the Weapons Group the facilities required to enable us to do whatever part of the work we agree with the U.S. should be done by us."[279]

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[271] TNA, AIR2/13733, Progress Report on Nuclear Weapons, 30/09/1957, TNA, DEFE7/923, Atomic Weapons Trials Executive – Operation Grapple, 17/04/1958 & Walker, (2010), p.65
[272] TNA, AB16/2303, Suspension of Atomic Weapons Trials, Personal Message from Sir William Penney to AWRE Staff, 25/08/1958
[273] Arnold and Pyne, (2001), p.271 & Baylis, (2008), p.452
[274] Arnold and Pyne, (2001), p.214-215
[275] Moore, (2004), p.216
[276] Arnold and Pyne, (2001), p.215-217
[277] TNA, AB16/1910, Future Policy in the Field of Nuclear Weapons Research – Plowden to Prime Minister, 28/11/1958
[278] Ibid.,
[279] TNA, AB16/1910, Future Policy in the Field of Nuclear Weapons Research – Plowden to Prime Minister, 28/11/1958, TNA, AB16/1910, Penney to Plowden, 20/11/1958 & Arnold and Pyne, (2001), p.213

In addition to financial pressure, Aldermaston was facing increasingly vociferous protests from disarmament organisations. In 1958, Macklen complained that AWRE was feeling "somewhat isolated" with the lack of government support in the face of protests.[280] In 1959, the Campaign for Nuclear Disarmament started annual marches from Aldermaston to London. [281] Although staff and union representatives denied that protests "had any noticeable effect on the morale of the establishment," Penney was forced to reply to protest representatives.[282] In June 1960, "staff at Aldermaston [raised to UKAEA administrators] the question of the future of the site in the event of political changes of policy."[283] Popular pressure within Aldermaston had led to the foundation of the "Penney Committee" which had been tasked to examine potential future work for potential redundancies.[284] The fear of political decisions quickly removing work was not an irrational fear: the Labour party adopted unilateral nuclear disarmament as a policy position at their party conference in October 1960 before it was overturned the next year.[285]

Rather than immediately contracting, AWRE continued to expand beyond 1958 "to meet urgent but short-term weapons programme needs."[286] The demands of anglicisation meant that total staff figures for March 1958 stood at 8273 but reached 8621 by August 1960. [287] The sustainability of this situation was a source of concern amongst senior AWRE figures.[288] A 1959 AWRE management paper noted that "from the [perspective of] staff morale alone, the oft reported assurance that 'either work will be found' is wearing thin, particularly in view of the failure of past attempts to diversify the programme."[289] The paper presses that there needed to be "an adequate solution to this problem… the Authority must, after consultation with the MoD, made [sic - make] appropriate provision in their forward planning for the utilisation of AWRE staff and facilities."[290] This clearly highlights the dormant morale problems at the establishment related to diversification: if staffing levels were at an all-time high only to meet immediate needs, AWRE appeared likely to contract in the future unless further development work could be found. [291]

[280] TNA, DEFE7/923, Macklen to Richard Powell, 03/03/1958
[281] Corbett, (2017), p.108
[282] TNA, ES1/1503, Notes of a Meeting – A6/916/01, 18/04/1958
[283] TNA, AB16/2303, Hegarty to Moberly, 03/06/1960
[284] Ibid., This was not the same institution as the board tasked to investigate Windscale. Consisted of William Penney, William Cook, Leonard Owen, Claude Pelly, Dr. Schonland and Dr. Levin. TNA, ES15/5, AWRE Management Committee Meeting, 25/03/1958
[285] Corbett, (2017), p.109
[286] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group Meeting, 01/12/1960
[287] TNA, AB16/2303, Comparison of Actual with Estimated Strengths, (n.d.)
[288] TNA, AB16/3362, Plowden to Penney, 25/06/1958
[289] TNA, ES1/1323, A Civil Programme for AWRE, (n.d.)
[290] Ibid.,
[291] Walker, (2010), p.82-83

Conclusion

This chapter has traced several interlinked processes that led AWRE from one crisis of retaining skills to another. Although initially a boon, the first factor in this cycle was the considerable political commitment behind Britain's thermonuclear programme. This meant that AWRE received all the resources that it needed to fast track completion of a megaton test. This was essential given that the prospect of an internationally agreed testing moratorium prompted the programme to be carried out at a tempo faster than intended. The urgency of the effort meant that significant investments were made to ensure that retention and recruitment of staff was improved between 1954 and 1958. This was to the extent that the Treasury had difficulty providing oversight over spending at Aldermaston. While considerable political support mobilised in favour of the agent's interests should have been the ideal conditions to operate under, AWRE's rapid expansion created severe long-term knowledge management issues as it meant that the organisation had to significantly expand in a brief period.

As raised by some secondary sources, contemporary documents concur that AWRE's expansion intersected with and was further complicated by the recent transition to the UKAEA. Regardless of any long-term benefits, the timing of the transition assisted in the creation of a morale crisis wherein AWRE required extraordinary measures to retain staff with the perceived essential skills and knowledge necessary to conduct the thermonuclear project.

Through a combination of these two processes, a major social development amongst staff at Aldermaston occurred. Conditions emerging from the 1954 morale crisis meant that contemporaries began to recognise their own (if disputed) tacit knowledge. Select staff with nuclear weapons specific skills began to refer to themselves as 'weaponeers.' This realisation had significant and lasting consequences. As a precursor to arguments over nuclear 'uninvention' at the end of the Cold War, the weapons establishment argued that retention of 'weaponeers' was crucial if the institution was to remain viable.

Only through good leadership, offering housing and promises over the long-term prospects of the establishment were staff accrued at a rate that allowed AWRE to successfully deliver full thermonuclear tests before the imposition of a testing moratorium. The limited secondary literature on Britain's thermonuclear programme cites the role of William Cook in improving the culture at Aldermaston to facilitate knowledge transmission. This chapter has highlighted the key role that

Cook had in improving retention and recruitment mechanisms but notes that he still faced inherent limitations due to the secrecy imposed upon Aldermaston. Fears over Soviet espionage meant that AWRE restricted knowledge on a 'need to know' basis, so much so that contemporaries were concerned about the education of the next generation of staff. AWRE's managers had intended to acquire ancillary projects ('diversification') to retain tacit knowledge and solve the staffing situation in the long term. However, due to the prioritisation of the Grapple tests, AWRE did not acquire additional projects during this period.

While the conclusion of the Mutual Defence Agreement of 1958 initially brought new work with the anglicisation of American designs, concerns re-emerged over the long-term sustainability of the British nuclear weapons project. This left AWRE by the end of the decade acutely aware of the necessity of maintaining a skills base in order to practice its primary function of providing the deterrent but that it also had to be proactive in acquiring future projects. When Britain completed its Grapple tests, this meant that AWRE had to either find work to sustain its highest staffing levels or the establishment would lose employees with valuable testing experience. The processes that had emerged at AWRE in the 1950s would direct the institution to campaign for its interests ever more vociferously in the 1960s.

Chapter 5: Uninvention and AWRE in the 1960s (1960-1970)

Introduction

This chapter details how AWRE justified the early efforts of the Polaris Improvement Programme in terms of maintaining their conception of tacit knowledge. It will do so by tracing five interlinked mechanisms. Firstly, this chapter demonstrates that the threat of nuclear 'uninvention' via skill loss was first clearly invoked in 1962 as a continuation of concerns over the loss of 'weaponeers' as explored in the prior chapter.[1] Secondly, despite temporary alleviation, it will be shown that fears over a 'brain drain,' exacerbated by the failure of diversification to reassure AWRE staff between 1962 and 1966, resulted in a new morale crisis. Thirdly, it is argued that the initial proposal to work on a Polaris Improvement Programme in 1966 was justified on retaining expertise at Aldermaston. The chapter then analyses the Kings Norton Inquiry which was an attempt by those outside of AWRE to determine its minimum manpower requirements in response to skill-based arguments. It is demonstrated that due to a combination of the final two processes of weak external oversight from the Ministry of Technology or UKAEA and with AWRE justifying further research on the possibility of 'uninvention,' the weapons establishment was able to prevent critique of what they suggested was their minimum complement of staff. These five prior processes created the necessary conditions that would allow the Polaris Improvement Programme to mature into the Chevaline project. The cyclical invocation of the 'uninvention' arguments in 1962 and again from 1966 onwards demonstrates that when a future plan of work for AWRE was lacking, potential loss of required skills was raised to politicians as a mechanism to secure the establishment's institutional interests.

Lobbying of this nature could only be expected according to a contemporary critics such as Zuckerman as "[AWRE's staff's] future depended on having Ministers and civil servants believe that their work was essential to the national interest."[2] Zuckerman's belief that it was nuclear weapons laboratories that drove nuclear weapons innovations, rather than armed services or politicians has been interpreted as the "Zuckerman Thesis."[3] This was later examined by Spinardi, who discounted it in the British historical experience except in the case of Chevaline (the final product of the Polaris Improvement Programme).[4] This chapter concurs, but will demonstrate that the effective use of the

[1] See Mackenzie and Spinardi, (1995), p44. On the history of the claimed fragility of tacit knowledge in the US nuclear weapons establishment, see Sims and Henke, (2012).
[2] Zuckerman, (1989), p.386
[3] Spinardi, (1997), p.548
[4] Ibid., p.574

nuclear 'uninvention' argument by AWRE in the 1960s was the key factor in securing Polaris Improvement through analysis of archival material. However, as this chapter will examine, the extent to which Aldermaston's lobbying was successful in 1962 compared to 1968 is highly divergent. Factors such as oversight over the nuclear weapons establishment, the failure of diversification, the personal influence of select civil servants and the government's overall commitment to defence reductions were highly influential.

AWRE by 1962: On the Brink?

As outlined in the previous chapter, since 1954, AWRE had enjoyed considerable commitment from Whitehall as the nation embarked upon its thermonuclear programme. The high priority attached to achieving thermonuclear status before a testing moratorium and the practicalities of conducting atmospheric nuclear tests had created a large body of manpower within AWRE.[5] Nuclear weapons research and production retained precedence beyond 1958 due to Duncan Sandys' doctrine of nuclear deterrence.[6] In addition, to secure the MDA (Mutual Defence Agreement) with the United States, Britain committed to an expansive sufficient independent deterrent programme which "resembled a long shopping list of items."[7] However, such a policy was immensely expensive and as seen in the previous chapter, AWRE had successfully argued against an immediate reduction to its budget following the conclusion of the MDA in 1958.[8] While AWRE had a "formidable" workload, it was subject to uncertainty and cancellations; Sandys' policy lacked firm Ministerial approval and pressure from within Whitehall built to reduce spending on both the nuclear deterrent and defence in general.[9] Macmillan initiated a reassessment of Britain's relative power with the 'Future Policy Study' on 7th June 1959.[10] One of the working groups was the British Nuclear Deterrent Study Group (BNDSG), which deliberated what nuclear force would be sufficient for Britain's needs between 1959 and 1962.[11] While resolving upon a sufficient 'future policy', only short term funding to maintain existing research and development programmes was approved for

[5] Pyne, (2004), p.G-8
[6] Moore, (2010), p.4
[7] Jones, (1)(2017), p.111
[8] Ibid., p.111 & p.237: The nuclear weapons programme (production and research) was costing £5.5 million a month in 1960/1961
[9] Simpson, (1986), p.154, Jones, (1)(2017), p.193
[10] Jones, (1)(2017), p.159
[11] Twigge and Scott, (2000), p.49

AWRE until 1962. This led to considerable uncertainty over the establishment's future, but it would not be an immediate issue due to the tranche of work provided after the 1958 MDA.[12]

Without clarification, the long-term prospects for AWRE were becoming increasingly threatened. Harold Watkinson, the then Minister of Defence highlighted to the Prime Minister at a Defence cabinet meeting in December 1959 that "AWRE...[was] faced with a serious problem…in the absence of a clearly defined programme they were experiencing difficulty in keeping together their highly skilled scientific staff… Every months delay…was liable to cause further losses of skilled staff."[13] Nonetheless, the Chancellor bluntly forwarded that he "would be unable to agree to any [commitments] but urgent and short-term requirements" until a longer term policy was agreed upon.[14] The inability to fix upon a programme is best exemplified with the choice to replace the Red Beard nuclear weapon with a new generation device – although Operational Requirement 1177 was issued in 1960, development and production was only authorised in mid-1962.[15] On the basis of accepting the findings of a BNDSG report in 1960, Macmillan moved to severely cut nuclear defence spending, reorienting Britain's nuclear force to a political deterrent rather than a warfighting instrument.[16] However, even this would prove an incremental stage, as deciding upon how to operationalise a programme of cutting spending on nuclear weapons would take a further two years. Fixing upon a definitive nuclear weapons development programme was challenging as major defence decisions were necessarily interlinked: determinations on overall force structure, fissile material production and the acquisition of new delivery aircraft (such as TSR2) all had to be concluded beforehand.[17]

This lingering policy of reductions left both AWRE management and staff aware that imminent cuts to their programmes were always possible, but unclear on the timing or the extent to which they would be conducted.[18] Zuckerman noted the early 1960s were a "worrisome time for the Aldermaston scientists and engineers;" in December 1960, Penney refused to advocate for the recruitment of an extra 300 staff to meet short term needs on the basis that they would soon be

[12] Ibid., p.194, see also previous chapter
[13] Jones, (1)(2017), p.194 & CAB131/23, Cabinet Meeting Minutes, 31/12/1959
[14] CAB131/23, Cabinet Meeting Minutes, 31/12/1959
[15] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962. Cabinet recognised the "military case," but doubted that it held sufficient "importance…to justify the expenditure involved." TNA, CAB131/27, Cabinet Defence Committee Minutes, 06/06/1962
[16] Jones, (1)(2017), p.199, p.235-236 & Moore, (2010), p.146, TNA, CAB131/23, Cabinet Meeting Minutes, 31/12/1959 & CAB131/23, Cabinet Meeting Minutes, 20/02/1960
[17] Walker, (2019), p.5-6
[18] However, the exact scale of cutbacks to manpower were kept from staff even as plans were made in late 1962. TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962

surplus to requirements.[19] Nonetheless, some new research continued; in 1961, the UKAEA Chairman actively advocated for new underground tests to be conducted in Nevada on new nuclear primary concepts. These tests were conducted in 1962 and proved successful and of interest to the Americans.[20] Nevertheless, as Moore observes, the economies envisaged for AWRE in the early 1960s were to the extent that Macmillan did not provision for any successor delivery system beyond the 1970s; for a time, according to Moore, this amounted to "unilateral nuclear disarmament in the making."[21] Watkinson was charged with the detailed practicalities of planning broad reductions in nuclear weapons research and production.[22] Watkinson's plans were being formulated during a period of economic turbulence for Britain, so it is unsurprising that Jones quotes Watkinson as stating that his reductions were being considered "not on the grounds of strategy and tactics but on the basis that we may be forced into it by budgetary reasons."[23]

If 1959 to 1961 had been a protracted period of uncertainty of AWRE, then 1962 saw the confirmation of the establishment's fears over reductions in their programmes. The unpredictability of cuts to the nuclear weapons development agenda seemed to be enhanced by the replacement of Watkinson by Thorneycroft as Minister of Defence in July of 1962 following Macmillan's 'Night of the Long Knives.' Thorneycroft appears to have been even more intent on seeing cuts for AWRE through: Zuckerman alleges that he cancelled the Blue Water tactical nuclear weapons programme with "practically no consultation" in August 1962.[24] In terms of complying with Watkinson's and then Thorneycroft's plans, AWRE senior leadership estimated in 1962 that only "50 percent of the existing Establishment" staff would be needed to provide a "minimum complement" by 1967.[25] This decline

[19] Zuckerman, (1989), p.386 & TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group Meeting, 01/12/1960

[20] Moore, (2010), p.199-202

[21] Ibid., p.146. This was in large part because it was policy that "No provision had been made for research, development or production for the purpose of maintaining our independent contribution to the strategic deterrent when the system based on manned bombers using SKYBOLT came to the end of its useful life." - TNA, CAB131/27, Cabinet Defence Committee Minutes, 12/01/1962

[22] Moore, (2010), p.161 & 166

[23] Jones, (1)(2017), p.316, see also Baylis, (2008), p.452. The strategic rationale offered for this change in the February 1962 Statement on Defence was the acceptance of mutual vulnerability and the inability to win a nuclear war. TNA, CAB131/27, Statement on Defence, 02/1962

[24] Zuckerman, (1989), p.248. This however appears to be a significant exaggeration: Thorneycroft favoured cancelling Blue Water in July 1962 shortly after his induction into his new role with Cabinet. TNA, CAB131/27, Cabinet Defence Committee Minutes, 31/07/1962. This was followed by some deliberation in early August 1962 wherein Cabinet, at the instigation of the Prime Minister, reflected on the June decision on the basis of NATO nuclear doctrine. Zuckerman was present at this meeting. TNA, CAB131/27, Defence Committee - Defence Programme, 03/08/1962

[25] TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962 & TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962 & TNA, AB16/3240, Weapons Programme: Defence Committee Papers, 28/06/1962. How this figure was deduced by the UKAEA upon is unclear (also described as an "estimate"). Given the reductions

was necessary due to a proposed year on year decline of the research and development budget at AWRE that would save £13 million by 1968.[26]

Such a reversal in staffing levels at the establishment would be unprecedented and be in stark contrast to the "intensive" recruitment that had occurred before and after the Grapple tests in the 1950s, which had seen manpower at AWRE reach its zenith at 8715 staff by 1962.[27] These staffing levels were fine as long as sufficient work of high priority was available, but with the process of anglicization of American designs and the design of a Skybolt warhead nearing completion, such work was coming to a close. When it had appeared that AWRE would have to support a defence policy premised on Sandys 1957 White Paper, further work appeared secure. However, the UKAEA Chairman noted that within a short period of time, "Blue Water has been cancelled", "No nuclear warhead is required for Seaslug" and a range of tactical munitions for the army had been "dropped."[28] The cuts to tactical nuclear weapons were a particular blow as they would have provided new avenues for research at the establishment and had been ascribed a high priority in 1958.[29] While research on a replacement for Red Beard (what would eventually produce the WE-177 series) and a high yield warhead for Skybolt had been authorised, the lack of a varied programme and a successor to Skybolt meant that the dearth of projects would "radically affect the future size and shape of AWRE" from spring 1964.[30] Due to the "recent decisions on defence [which] have produced a large reduction planned warhead development and production programme," management within the UKAEA and AWRE realised that further work was needed.[31] Unlike in 1953-1954, it did not appear that this was likely to be forthcoming, so further work had to be actively pursued to rectify the situation.

Appeals for Assistance

envisaged, these figures seem to have been accepted by NRDC officials relatively uncritically. Moore gives the envisaged figure as 4800 by 1967/68. Moore, (2010), p.199

[26] TNA, AB16/3240, Re-estimates of Defence Receipts and Expenditure, 12/07/1962

[27] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party – Appendix 1 to Annex 5, (n.d.), TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962

[28] TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962. See also Moore, (2010), p.196 & Zuckerman, (1989), p.210

[29] AVIA 65/1770, P.S./Minister to U.S.(LGW), U.S.(MW) & U.S.(SAW), 05/11/1958

[30] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962

[31] TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962

Impending work shortfalls prompted senior AWRE figures and sympathetic civil servants to lobby both from within the UKAEA and then to central government to stress the need for further work. For example, in resolving manpower issues, AWRE's 'Penney' Committee meeting on 1st December 1960 called for direct representations to be made to the Secretary of State for Defence (SofS), the Minister for Science and the Permanent Secretary for the MoD to convey their needs.[32] As previous chapters have seen, this had proven relatively successful in the past, for instance, with Portal staving off HER's cancellation and Penney securing the initial diversification efforts.[33] In contrast, the appeals made between 1960 and 1962 were largely unsuccessful.

This was due in part to the firm commitment made by the Macmillan government to reduce defence spending, with a particular eye on nuclear weapons research and development.[34] Macmillan was unlikely to prove personally sympathetic to these efforts; he reportedly advised Zuckerman in 1960 that if research projects "are likely to be cancelled, kill them when they are no larger than sprats," rather than allow them to grow to maturity.[35] With Sandys replaced and Watkinson and Thorneycroft selected as Ministers of Defence to oversee reductions, AWRE would only find limited support at a Ministerial level.[36] When the SofS and Chancellor of the Exchequer where both in agreement of the need to significantly cut defence spending across all branches, there was little that lobbying from AWRE could achieve when savings of £45 million from the nuclear weapons programme were envisaged.[37] Even Sandys, now as Minister of Aviation in 1960, recognised that "he was concerned at the high rate of expenditure on nuclear weapons of all kinds." Nevertheless, He rather impractically hoped that "there might be scope for making economies" that wouldn't impact either the tactical or strategic effort.[38] As both Moore and Jones observe, a further factor mitigating these appeals was that the connection that AWRE had periodically enjoyed to relevant Ministers was attenuated by the increasingly important role of the Nuclear Requirements for Defence Committee (NRDC) which asserted "greater 'civilian' administrative control over the detailed nuclear weapons agenda."[39] This attenuated the direct connection that Aldermaston had to ministers. Given the

[32] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group Meeting, 01/12/1960
[33] See Chapter 3
[34] TNA, CAB131/27, Defence Committee - 1956/1966 Defence Costings, 27/07/1962 & TNA, CAB131/27, Defence Committee - Defence Expenditure, 13/06/1962
[35] Zuckerman, (1989), p.20
[36] Jones, (1)(2017), p.166 & TNA, CAB134/2239, NRDC Minutes, 17/06/1962
[37] TNA, CAB131/27, Defence Committee - 1956/1966 Defence Costings, 27/07/1962 & TNA, CAB131/27, Defence Committee - Defence Expenditure, 13/06/1962
[38] TNA, CAB131/23, Cabinet Defence Committee Minutes, 17/10/1960
[39] Moore, (2010), p.14, Jones, (1)(2017), p.191-192

reduction of AWRE's influence, it is unsurprising that Moore rejected the 'Zuckerman thesis' (that weaponeers determined defence programmes) during this period.[40]

A further, less tangible aspect to AWRE's influence on Whitehall during this period was the role of the 'hidden Persuaders' as termed by Oikonomou.[41] As seen in prior chapters, the role of Cook and Penney to advocate on AWRE's behalf in concert with sympathetic officials and Ministers had likely influenced decisions in the establishments favour.[42] However, in the period from 1960-1962, these two men who had clearly established themselves within government circles played more peripheral roles: Penney was no longer AWRE's director and had instead become involved in directing arms control negotiations, being the executive for UKAEA Research and from 1961 was deputy chairman for the UKAEA.[43] Although Penney was involved in advocacy on behalf of AWRE through the 'Penney' committee, these other commitments appear to have been his main preoccupation. Similarly, Cook after having help conduct the Grapple tests, increasingly devoted his time to reactor development policy within the UKAEA and then conventional projects within the MoD as Zuckerman's Deputy. [44]

Zuckerman was perhaps at the zenith of his influence for defence policy as Chief Scientific Advisor at the MoD between 1960 and 1966. He was prominent in "the gradual move away from the massive-retaliation strategy of… 1957… [towards a policy based] more on conventional defence."[45] In doing so, he agitated against further tactical nuclear weapons programmes that would have provided work for Aldermaston.[46] In place of Cook and Penney, the principle advocates for AWRE's interests were Roger Makins as chairman of the UKAEA and Nyman Levin as AWRE's Director (after Penney's departure in 1959). [47] While Moore credits Makins as being an "exceptionally powerful figure" and Levin as enjoying "considerable prestige within the defence establishment," they do not appear to have had the same influence as Cook and Penney.[48] Makins certainly advocated for AWRE at a cabinet level but it appears that Levin was not as able in this regard as his predecessor.[49] While this almost certainly reflected the diminished influence of AWRE on government as a result of the foundation of the NRDC, Levin simply did not have the same high profile as his contemporaries.

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[40] Moore, (2010), p.238 – between 1958 and 1964
[41] Oikonomou, (2011), p.1
[42] Although hard to substantiate a negative, Penney is not cited in Cabinet discussion from this era.
[43] Makins, (1994), p.292-293
[44] Penney and Macklen, (1987), p.55-56
[45] Moore, (2010), p.4 & Zuckerman, (1989), p.174. Zuckerman was also directly advising Wilson on nuclear weapons matters.
[46] Moore, (2010), p.60
[47] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[48] Moore, (2010), p.20-21
[49] For examples of Makins efforts, see TNA, CAB134/2239, NRDC Minutes, 17/06/1962

According to the New Scientist in 1959, he was "little known outside the spheres in which he… [had] worked" when he became Director and is only mentioned by name in the official history of the era once.[50]

Uninvention Arguments

Even with reduced influence, AWRE still attempted to make the case for retaining spending at the establishment. Several main rationales for retaining the staffing strength at AWRE were advanced. Although ultimately unsuccessful during this period, they would exert a powerful influence on the future of the UK's nuclear weapons programme; as will be seen, these arguments would largely be repeated in the 1968 Kings Norton inquiry and the MoD's justification for what would become Chevaline. This highlights the cyclical nature of AWRE's sustainability issues in the 1960s, where the establishment's management pushed for further research on the grounds that it was the only way to preserve present capabilities.

Retaining Skills

The main argument cited by AWRE managers in favour of retaining a large cohort within the establishment in 1962 was that the accrued expertise within the programme was under threat.[51] Appeals made particular mention of the unique skills on offer by the staff and the suitability of the infrastructure of Aldermaston for civil work and how this could be lost if not utilised.[52] Nevertheless, calls in favour of diverting resources to the weapons establishment premised on skills were not unprecedented. As previous chapters have seen, both during the HER programme and especially in 1953-1954, similar arguments (such as those based on the unique skills of the 'weaponeers') were periodically marshalled to leverage better resources for the weapons establishment.[53]

However, a clear development on arguments premised on the retention of skills can be observed to have developed between 1959 and 1962 as the prospect of cuts became more apparent. As previously cited, in 1960 Watkinson warned the Prime Minister that delays in deciding

[50] Jones, (1)(2017), p.467 & New Scientist, (1959). Regardless of his impact on public policy, Levin was the first to advance AWRE's version of the 'uninvention' argument that that will be discussed in detail. TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group Meeting, 01/12/1960
[51] TNA, CAB134/2239, NRDC Minutes, 17/06/1962
[52] Ibid.,
[53] See Chapters 3 & 4

a defence policy "was liable to cause further losses of skilled staff."[54] Levin stated on 1st December 1960 that even with a reduced staffing level, "so long as any weapons remained in service, there would be post-design problems and surveillance which would require a wide range of qualified people. It would consequently be necessary to keep a broadly-based team and to give this team enough general research and development to hold it together."[55] This was the first call for research to be diverted to AWRE based on maintaining the nuclear arsenal. Jones notes that the Minister for Defence cited a skills based argument in 1961 to forestall an immediate cut to the nuclear weapons research programme on the basis that severe cuts would be "irreversible" and without study, would be "cutting blind."[56] By 17th July 1962, it was reiterated at the highest levels by "Sir Roger Makins [chairman of the UKAEA]… [who] said that the design teams at Aldermaston must be able to look forward to a substantial programme of further development work if they were to be kept together and available for unforeseen tasks."[57] In this meeting of the Nuclear Requirements for Defence Committee, Makins therefore advocated an "Advanced Warhead Development Programme" expressly for the institutional interests of skill retention of the establishment, rather than the direct utility or deterrent value of the weapons that would be developed themselves. [58] It is notable that Levin's call for further 'general' research had developed into calls for military work by 1962.

Premised on fragility, the 1962 iteration of these arguments had matured into a clearly recognisable expression of the need to retain the somatic tacit knowledge imbued in the 'weaponeers' as recognised by MacKenzie and Spinardi, but also on a collective level forwarded by Sims.[59] For example, while not referenced to as 'weaponeers' to Ministers in documents from 1962, staff collectively and individually held "special skills." [60] In addition, for the establishment to function, these staff needed to be "kept together" for the weapons establishment to function.[61] This novel arrangement of arguments premised on skills suggests a managerial awareness of AWRE being forwarded as a delicate socio-technical system where knowledge management was key.

Premised on AWRE's fragility, a further development was framing disruption to its work as a near existential threat. Maximalist consequences were threatened if AWRE's research agenda was disrupted by the NRDC's proposals to the future of the establishment. For example, The UKAEA stated in a memorandum that rather than further research being degraded or the establishment

[54] Jones, (1)(2017), p.194
[55] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group Meeting, 01/12/1960
[56] Jones, (1)(2017), p.237
[57] TNA, CAB134/2239, NRDC Minutes, 17/06/1962
[58] Ibid.,
[59] Mackenzie and Spinardi, (1995), p.44 & Sims, (2007)
[60] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[61] TNA, CAB134/2239, NRDC Minutes, 17/06/1962

being limited to maintenance in the event of reductions, "it will be **impossible** [emphasis added] for the authority to provide continuing support to the Services on a post design basis without an appropriate research and development programme."[62] Along with previous quotes on the "virtually irreversible" nature of the potential reductions, such rhetoric served to convey the permanence of any reverse.[63] Although more moderate, Makins noted that maintaining the quality of staff at AWRE would be "notoriously difficult to do in an establishment which is being run down."[64] This potentially differs from the prior warnings over the need for greater priority and diversification in both 1954 and during the HER programme, where delays were threatened rather than the ability to complete the project.[65] While it is impossible to tell whether the reductions foreseen in 1962 may have produced such effects, it is clear that both Makins, the UKAEA and AWRE wanted to convey the fragility of the body of skill needed to maintain any deterrent.

A New Idea?

When the conceptions of tacit knowledge, AWRE as a socio-technical system and the fragile maintenance of both were combined, a new argument for influencing policy was formed. This was a fundamentally novel argument that asserted the imperative for the maintenance of quality research in order to satisfy the above conditions, under threat of inadvertent future disarmament that itself would be near impossible to prevent. Although clearly not couched in the same terms, the concepts involved directly mirror MacKenzie and Spinardi's "uninvention hypothesis."[66] While MacKenzie and Spinardi primarily based their argument on observations and interviews from the American nuclear establishment in the 1990s, this confirms the hypothesis offered in the framework that a similar process was used in 1960s Britain as a mechanism to lobby against staff reductions.

The logical conclusion of an argument premised on the fragility of knowledge management in AWRE was that more work would have to be found for the establishment to retain the current level of staff. This was clearly the line of argumentation forwarded by Makins in 1962, where in response to the proposed economies at Aldermaston, he stated that "the quality of research and

[62] TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962
[63] TNA, CAB134/2239, NRDC Minutes, 17/06/1962
[64] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[65] This was a possibility for both the fission and fusion projects, but as seen in prior chapters, for exogenous factors. In the fission programmes case: the threat of imminent war and the need to prioritise resources and for the fusion programme, the need to complete tests before the imposition of a testing moratorium.
[66] MacKenzie and Spinardi, (1995), p.44. The "virtually irreversible" loss of AWRE matches MacKenzie and Spinardi's conception of their uninvention hypothesis.

development work on nuclear warhead… technology must be maintained at a high level."[67] However, as seen in the prior chapter and by recalling promises that had been made to the establishment and appealing to tacit knowledge skills and the strategic importance of AWRE (now framed around the MDA), AWRE's response to the imminent crisis in 1962 can be seen as the culmination of prior trends rather than a revolutionary change. When faced with the cancellation of the atomic programme forwarded by Tizard in 1949, Penney and Portal had to actively lobby against cancellation.[68] During the difficulties experienced by AWRE in 1953-1954, Penney had also called for clarification on government weapons policy and pushed for diversification work to be brought to the establishment.[69] With the prospect of losing half its strength unless further work could be found, it was recognised from 1960 onwards that AWRE would have to be far more proactive in obtaining new work.[70] A 1961 paper by Hitchman assessing the prospects for civil work for AWRE concluded that the establishment should "[smooth] out fluctuations in the Weapons Group defence load wherever possible, even to the extent of modifying the phasing of items in the Defence Programme if this is possible" and also that "the Weapons Group themselves will need to be the prime agents in seeking appropriate civil work."[71] The need to become heterogenous engineers had been fully realised.

Promises of Diversification and Staff Morale

If retention of skills formed the primary argument in favour of AWRE, and retention was based on the staff's perception of the viability of their careers at the establishment, then a subcomponent of the skills argument was for fulfilling promises made to staff in the 1950s. Repeated promises had been made by multiple Conservative politicians about the security that would be enjoyed by the workforce at AWRE, regardless of the disarmament situation. As already seen, job security and staff morale had been a perennial issue with the establishment since the initiation of the nuclear project. This was noted in a 1962 paper by the UKAEA, where it was made clear that for AWRE staff, "the possibility of redundancy in the Weapons Group has long been in their minds and to maintain their morale, assurances at the highest level have had to be given that

[67] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[68] See Chapter 3
[69] TNA, AB41/514, AEX Minutes, 03/06/1954
[70] TNA, ES15/5, AWRE Management Committee Meeting, 25/03/1958 & TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962
[71] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group - Resources in the Weapons Group, 19/11/1962

the skills assembled within the Weapons Group would not be dissipated."[72] The potential morale crisis in the face of the planned reductions had not been realised by 1962 as "there has been no disclosure to the Staff or Trade Unions of the magnitude of the staff surpluses" envisaged.[73] Prior promises compiled in UKAEA documents included those made by Anthony Eden, Harold MacMillan, Lord Cherwell, William Penney and the UKAEA board member for AWRE, Claude Pelly, as well as other UKAEA officials, ranging from 1954 to 1960.[74] As the crisis was occurring during Macmillan's second government, it appears that these promises were being cited as an implicit threat to the government's reputation were they to be broken.

Maintaining the 1958 MDA

The third argument employed in support of retaining as many staff as possible at AWRE which related to maintaining accumulated skills was by recalling the 1958 MDA. As highlighted heavily by AWRE, the MDA arrangement was predicated on "making substantial and material contributions thereto [sic]."[75] It was clearly conveyed by Makins that without a further research programme, this agreement would be endangered.[76] Makins pushed for cooperation and involvement in upcoming US nuclear weapons tests, both as a way to continue cooperation, but also to satisfy the need for further research at the establishment.[77] Furthermore, the importance of the arrangement to the current weapons programme was emphasised through "the valuable help in weapon design and technology" it provided as well as design details and the influence it allowed the UK and AWRE to have on future American systems.[78] Moore states that this citation of the MDA in conjunction with work at AWRE "appears to have been the first use of an argument which, by the late 1960s and early 1970s, would dominate Whitehall discussion of nuclear weapons."[79]

However, the previous chapter saw that the continuation of a British design programme was invoked almost immediately after the conclusion of the 1958 MDA by Penney to save AWRE from a

[72] TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962
[73] Ibid.,
[74] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group - Resources in the Weapons Group, Report, Appendix VI, VII, VIII & IX, 19/11/1962
[75] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[76] Ibid.,
[77] Walker, (2010), p.226
[78] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[79] Moore, (2010), p.199

tranche of economies.[80] When this possibility was again raised in 1959 with investigations into the future policy for deterrence, the BNDSG found that Britain would need to maintain its nuclear contribution "in terms of both skill and of power."[81] Brundrett (as chairman of the Defence Research Policy Committee) had attempted to argue in 1959 that it was the size of the arsenal itself that guaranteed American cooperation.[82] Nevertheless, by 1962, AWRE were clearly linking skills, the MDA and the need for a sustainable future for the British nuclear weapons research and development programme more clearly than otherwise thus far expressed. The importance of effective cooperation with the United States for AWRE's future was to be underlined mere months after Makins had made his case to the NRDC with the American cancellation of Skybolt and the subsequent need to acquire Polaris.

Using Uninvention: Success or Failure?

While this section has presented the arguments used by AWRE to forestall planned reductions to the establishment, it must be highlighted that in 1962, they were largely unsuccessful. The plan for the development of nuclear warheads endorsed to Ministers by the NRDC through document ND(62)13 in October 1962 foresaw only the finalisation of a warhead for Skybolt and an eventual programme for replacing Red Beard.[83] In addition, there would only be 90 Skybolt warheads and the number of approved Red Snow warheads was reduced.[84] No significant new nuclear weapons research work was envisaged. Compared to previously imagined efforts, this was a highly limited programme that would necessitate the fifty percent reductions envisaged by the UKAEA at AWRE by 1967.[85] Given the warnings that AWRE management had been issuing since late 1959 as to the implications of reductions, this represented a significant failure in influencing policy towards the establishment's institutional interests.

Despite the pessimistic outlook, there were elements to the policy endorsed by the ND(62)13 document that appear to suggest the general acceptance of AWRE's arguments in favour of retaining skills within the establishment. The "principles on which… [the] policy was based" included that "a post-design capability must be maintained," "research and development work…

[80] See Chapter 4. TNA, AB16/1910, Future Policy in the Field of Nuclear Weapons Research – Plowden to Prime Minister, 28/11/1958
[81] Jones, (1)(2017), p.175 & p.193
[82] Ibid., p.193
[83] TNA, CAB134/2241, British Programme of Underground Nuclear Tests 1965/66, 09/12/1964
[84] TNA, AB16/3240, Scott to Turnbull - Appendix, 22/08/1962
[85] TNA, CAB134/2241, British Programme of Underground Nuclear Tests 1965/66, 09/12/1964

must be maintained at a high level" and that this had to be done to uphold the 1958 MDA.[86] As will be shown, the acceptance of the arguments premised on a conception of tacit knowledge would prove extremely important to future programmes, as interested parties were able to cite this precedent in favour of further research.

Ultimately, what allowed AWRE to limit major and rapid reductions beyond 1962 were the events surrounding the Skybolt Crisis and the subsequent Nassau Agreement. While beyond the scope of this study, these events necessitated the development of a British warhead for the Polaris missile and the creation of a high yield gravity bomb (in addition to a low yield variant) to fill the 'deterrent gap.'[87] This new tranche of work was significant to AWRE as "up to mid-1966 the [nuclear weapons research and development] programme include[d] three new projects under preparation for Service use whereas the previous programme has only one such project after 1965 [low yield Red Beard replacement]."[88] As the UKAEA document notes, "the stretch-out in development programme eases the problem of matching staff and programme requirements."[89] While the new programmes envisaged would still necessitate reductions in manpower compared to its heights in 1962, this process could now be done more gradually. [90] In the short term, Moore notes that Aldermaston was in fact nearly "overloaded" with work due to Nassau, rather than from its lobbying efforts.[91]

Nevertheless, the principles espoused by UKAEA and AWRE officials between 1958 and 1962 and encoded in ND(62)13 appear to have been quickly used. The proposal paper ND(63)10 submitted January 1963 by the UKAEA in favour of a "three-year research programme involving nuclear tests… was chosen as the basis for maintaining an adequate research and development effort at Aldermaston, and an adequate level of collaboration with the U.S."[92] Further proposals for a research and testing agenda for AWRE for 1965 to 1966 were further premised on citing "ND(63)10 and previous papers."[93] Specifically, the need "not to prejudice… [AWRE's] ability to deal with any problems that might arise in respect to current nuclear weapons projects" was recognised.[94] Therefore, it is clear that ND(62)13 represented the acceptance of AWRE's skill based arguments which were subsequently used as precedent for expanding AWRE's research agenda (in addition to

[86] Ibid.,
[87] Moore, (2010), p.219
[88] TNA, CAB134/2241, British Programme of Underground Nuclear Tests 1965/66, 09/12/1964
[89] Ibid.,
[90] Ibid.,
[91] Moore, (2010), p.238
[92] TNA, DEFE24/291, NRDC Document - British Programme of Underground Tests 1965/66, 09/12/1964 & Moore, (2010), p.202
[93] TNA, DEFE24/291, NRDC Document - British Programme of Underground Tests 1965/66, 09/12/1964
[94] TNA, CAB134/2241, NRDC Minutes, 01/01/1964. Interestingly, the paper implies that prioritising testing could compromise a post design capability by either a lack of testing or too much of a focus on testing.

that precipitated by the Skybolt Crisis) after its near terminal decline in October 1962. This would continue to be cited throughout the 1960s, and then be used as justification for Polaris hardening.

Providing Diversification

As Penney had argued and supposedly settled in 1954, the agreed long term solution to AWRE's staffing problems was a programme of diversification where other military related nuclear research would be brought under the establishment's remit.[95] When faced with insecurity after 1958, UKAEA officials noted in 1960 that the "staff side… [have] a great interest in this matter [diversification] and…[have] made no secret of its anxieties over the years."[96] As seen in the previous chapter, providing diversification work between 1954 and 1958 proved more aspirational rather than an achieved reality. This was not an imminent problem when AWRE had enough work but became increasingly important from 1958 onwards.[97]

Post 1958, AWRE pushed for greater civil reactor work, packaged service reactors or other relevant scientific work to cover their impending shortfall in the early 1960s, it achieved mixed results.[98] After explicitly lobbying the UKAEA for civil work between 1959 and 1960 in the face of MoD cuts, AWRE became involved in the development of technology and materials for the civil nuclear programme.[99] This work programme initially expanded to include researching and fabricating fuel to be used in breeder reactors, but was dealt a blow by the transfer of controlled fusion work to another UKAEA laboratory at Culham. [100] By 1962, some 260 AWRE staff were employed on diversified efforts, but this only accounted for "about" 10% of AWRE's strength engaged in "work in aid of the civil programme."[101] In the face of the cuts proposed to AWRE, it was recognised that "there… [was] no prospect of finding civil work to match the run-down," either

[95] TNA, AB41/588, Top Secret Annex to AEX 5th Meeting, 12/03/1955. See previous chapter.
[96] TNA, AB16/2303, Hegarty to Moberly, 03/06/1960
[97] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group - Resources in the Weapons Group, 19/11/1962
[98] TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group - Resources in the Weapons Group, 19/11/1962 & TNA, AB16/2303, UKAEA Committee on Civil Work in the Weapons Group Meeting, 01/12/1960
[99] TNA, ES1/1323, A Civil Programme for AWRE, (n.d.), Hawkings, (2000), p.24
[100] Pyne, (2004), p.G-8 & Hawkings, (2000), p.72
[101] TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962 – 95 employed in fast reactor fuel development, 30 in "Health and Safety basic research," 130 in "General Nuclear Research (Civil)." & TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962

through diversification or reallocation of staff to other UKAEA sections.[102] Diversification had by 1962 failed to make a serious contribution to retaining staff; if a cut in the weapons programme would result in a fifty percent reduction in staff, it was clearly falling short of its intended effect.

These failures were recognised by AWRE, and further efforts were made under the Turnbull Committee which sat from 1962 to 1963. Turnbull's findings were unsurprising given the prior rationale of the diversification effort. The committee's report recommended that work was needed that presented a "compelling intellectual challenge" to stop the "higher quality men" leaving.[103] Further suggestions were that "Defence Departments" and any "new proposals for the expansion of civil research and technology" should preferentially consider AWRE as the institution to fulfil their research and development contracts.[104] The Turnbull Committee's recommendations led to the initiation of a programme of non-nuclear research for AWRE that through the 1965 Science and Technology Act, "officially approved" of the new work, then already underway.[105] Although the Turnbull Committee had proceeded "on the assumption that it is not the intention to create work solely in order to keep people employed at Aldermaston and the other Weapons Group establishments," diversification's primary goal had always been to retain staff.[106]

Industrial Dislocation and 'Brain Drain'

The concern that AWRE would become unsustainable due to the loss of skill was further reinforced by the experiences of other defence institutions. This was best exemplified with the ramifications of the cancellation of both the Blue Water and Blue Streak nuclear rocket systems upon Britain's rocketry industry. When the Blue Water programme was cancelled in mid-1962, there were warnings that "the firm's [English Electric Aviation] guided weapons team would almost certainly have to… disperse."[107] When it came to Blue Streak, the concern was over "industrial dislocation" faced by the "sudden disruption" caused by cancellation.[108] While the Cabinet believed that the scientists and engineers would find other employment, Simpson notes that "the effect [of the Blue Streak cancellation and Polaris purchase]… was that the teams initially created to build the

[102] TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962
[103] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment - Appendix V, 07/1968
[104] Ibid.,
[105] Ibid.,
[106] Ibid.,
[107] TNA, CAB131/27, The Defence Programme - Appendix B - Blue Water, 13/07/1962
[108] TNA, CAB131/23, Blue Streak, 01/04/1960

Blue Streak vehicle were dispersed, and a hiatus of a decade then ensued when little experimental work took place in the United Kingdom in this area."[109] As with diversification in the nuclear programme, an attempt was made to use these skills in a civil capacity under the European Launcher Development Organisation, but this atrophied away by 1971. Stoddart claims that the protracted failure of this effort informed "bitter" government and UKAEA scientists about the low likelihood of being retained in the absence of military work by the late 1960s.[110]

While not conveyed in tacit knowledge terminology, there was a pervasive sense in the 1960s that institutional tacit knowledge was being lost to the "important and insidious threat" of a general UK wide 'brain drain.'[111] The belief, firmly established by a Royal Society report in 1963, suggested that British industry was suffering as highly qualified technical British professionals were going abroad (primarily to the United States), in the search for better conditions.[112] Harold Wilson's election campaign had explicitly pledged to react to this threat in his "white heat" of technology speech by establishing a Ministry of Technology to coordinate research efforts.[113] Responding to 'brain drain' concerns informed the context for which attempts to retain skills were made in across the UK in the 1960s. In December 1967 the Overseas Policy and Defence Official Working Party directly cited the potential for a "brain drain" in an explicit attempt to justify further work for AWRE.[114] Therefore, the experiences of the decline of the rocketry sector and the pervasive belief that skilled engineers were leaving the UK amplified AWRE's arguments in favour of retaining tacit knowledge in the late 1960s.

The Cycle Repeats 1964-1966

While the outcome of the Nassau Agreement delayed severe reductions in AWRE with a new programme of work ensuring for a time that it would "once again [be] very busy," what would happen when the current set of work was completed was an open question.[115] Ironically, AWRE had been further buoyed by their inability to copy the American designed Mk.58 warhead to Polaris,

[109] Simpson, (1986), p.168
[110] Stoddart, (2012), p.137
[111] Godwin et al, (2009), p.36
[112] Ibid., p.36
[113] Wilson, (1963)
[114] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967
[115] Moore, (2010), p.239

which necessitated further indigenous work.[116] Several joint nuclear tests were conducted with the United States between July 1964 and September 1965 to verify the new derived design.[117] Nevertheless, staffing levels specifically for nuclear weapons research and development (as opposed to total staff of AWRE) had reduced by 20% by 1964.[118] This was due to a deliberate policy of allowing wastage to outpace recruitment and was further increased by moving staff towards diversification work.[119]

However, in a significant development outlaid in ND(65)1, a numerical figure was placed on minimum staffing requirements.[120] In the context of keeping a "post design [AWRE] service" viable, the UKAEA asserted that "4500… [staff are] regarded as the minimum number required" for this to be upheld, with a further 1500 employed on 'diversified' civil work.[121] This figure had apparently been determined by Levin and expressed in a letter in April 1964.[122] This was clearly a warning at this stage, as the UKAEA had accepted that further reductions from the present staffing level at AWRE were agreeable and in terms of recommendations, only proposed that already approved testing and research be conducted.[123] This 'minimum' was still 500 staff above what had been envisaged as necessary for the establishment before the Skybolt Crisis as the smallest viable complement.[124] Although modest at this stage, the 6000 figure would prove pivotal in future debates over hardening Polaris.

The major event in 1964 that increased uncertainty for AWRE was the election of Labour with Harold Wilson as Prime Minister. Nuclear issues played a prominent part in the campaign; Wilson had claimed during campaigning that Polaris "will not be independent and it will not be British and it will not deter."[125] Wilson entered power threatening to cancel and renegotiate the Nassau Agreement and had a unilateralist contingent to his party. Nonetheless, he became mired in the reality of nuclear decision making with a split cabinet and the slimmest of majorities.[126] Political

[116] Ibid., p.237
[117] Stoddart, (2012), p.33, Moore, (2010), p.237 & Nuclear Weapon Archive, (2)(2007)
[118] Moore, (2010), p.238. Moore notes that while this may have been a "slight exaggeration," it was still above what would have been foreseen with the 50% reduction of 1962.
[119] TNA, CAB134/2241, British Programme of Underground Nuclear Tests 1965/66, 09/12/1964 - but this ensured that staff on diversified work were available for a future contingency.
[120] Ibid., As seen previously, only a 'estimate' that a 50% reduction of strength could be sustained was provided in 1962
[121] TNA, CAB134/2241, British Programme of Underground Nuclear Tests 1965/66, 09/12/1964 & Jones, (1)(2017), p.489 – Jones cites a letter from April 1964 where the 6000 figure is provided.
[122] Jones, (1)(2017), p.489
[123] TNA, CAB134/2241, British Programme of Underground Nuclear Tests 1965/66, 09/12/1964
[124] Jones, (1)(2017), p.489
[125] Mcintosh, (1990), p.19
[126] Ibid., p.19. For example, George Brown was initially in favour of cancelling the Polaris project. See Panton, (2004), p.C1

imperatives meant that little headway was made in dealing with future nuclear policy decisions during his first term. Protracted negotiations over the possibility of an 'Atlantic Nuclear Force' and then the potential for an early election delayed decision making, where forcing an issue would likely have negatively impacted Labour.[127] Therefore, despite the Labour 1964 manifesto being expressly against spending resources on "endless duplication of strategic nuclear weapons," little headway was made.[128]

However, Wilsons' first government made several important nuclear decisions. Firstly, AWRE was transferred to the newly created Ministry of Technology (MinTech) in 1967. This could have provided greater civilian oversight of the nuclear weapons programme, but as will be seen, MinTech officials were deliberately deprived of information. A further decision that impacted AWRE was the reduction of the number of planned Polaris submarines from five to four. While not ideal from AWRE's perspective, this would hardly have the same impact as the reductions envisaged in 1962 as research and development for Polaris warheads would have to continue irrespective of numbers produced.[129] The most impactful policy change implemented by the Wilson government to AWRE was the suspension of nuclear tests which had been carried out cooperatively with the United States.[130] Not only would this cut AWRE off from a source of work and testing experience, but would also undermine the US-UK nuclear relationship which was increasingly under strain over a lack of new information being provided by the UK. [131] In addition, the Labour government decided not to pursue acquiring America's next generation SLBM, Poseidon, despite some prompting from the Defence Secretary, Denis Healey.[132]

As a result of these decisions, and the lack of a plan for a successor system under the Macmillan government, Zuckerman stated that from 1964, "the supply of new nuclear weapons information to us was then beginning to taper off… the annual Stockade meetings [with the Americans] had started to become an embarrassment."[133] Zuckerman later alleged in his

[127] Jones, (2)(2017), p.97-98
[128] Labour Party (1964)
[129] This number being determined as four Polaris submarines were under construction. Stoddart, (2012), p.26
[130] Simpson, (1986), p.170
[131] Spinardi, (1997), p.560
[132] Stoddart, (2012), p.128 & p.137
This appears to have been based on practicalities rather than a publicly presented policy position. The intention not to commit to a new generation of nuclear weapons appears to have publicly emerged in June 1967 (Harold Wilson, HC Deb 13 Jun 1967 vol. 748 cc299) rather than in the labour manifesto of 1964: see Labour Party (1964) & Stoddart, (2012), p.273 & p.130. The 1964 manifesto criticised 'national' nuclear deterrents and "[wasteful]… endless duplication." Opposition to Poseidon may have been implicit but was not yet explicit. Zuckerman, (1989), p.394
[133] TNA, CAB168/25, Zuckerman to Prime Minister, 28/11/1968 & TNA, CAB168/27, ABM and Penetration Aid Systems (PENAIDS), (n.d.)

autobiography that this was a form of "blackmail" or "arm twisting" wherein "Aldermaston's friends" encouraged the Americans to deny information to the UK in order to guarantee they received greater resources to renew the "special, even if ephemeral, relationship."[134] This explains why some sources relay how Zuckerman "gleefully" relayed the Wilson government's lack of intent to develop new weapons in November 1965.[135] Whatever the tone, as a result of the position, US-UK Joint Working Group (JOWOG) stockade meetings were suspended, indicating the precariousness of the MDA.

Therefore, by the start of 1966, AWRE was entering a position remarkably like the one that it had faced between 1960 and 1962. As Jones observes, as Polaris and the WE-177B were entering production by 1966, "the immediate and pressing question" once again became the ongoing viability of AWRE as it was once again "locked in little more than a holding operation pending a deeper Ministerial consideration."[136] As with the situation in 1960-1962, it was unsurprising that Zuckerman claimed that "Aldermaston was pressing all the time" for additional work in 1966, when faced with a "looming gap in nuclear weapons research."[137] Jones cites a letter from the Permanent Secretary at the Ministry of Aviation to the PS MoD from January 1966 where he highlighted the "obvious risk… that the scientific momentum of Aldermaston will diminish" without further work.[138] Having called an election in February and winning an increased (and now workable) majority in the March 1966 election, Wilson was now in a stronger position to consider the future of the nuclear weapons programme. In the coming Cabinet debates over the future of Aldermaston, the same 'uninvention' argument from 1962 was re-used to an even greater extent, where the fragility of tacit knowledge was raised as imperilling the nuclear programme.

Another Morale Crisis? 1966 –1968

With the prior Wilson government having demonstrated considerable scepticism to further nuclear weapons developments, it appeared that AWRE would descend into a new crisis over the lack of work. This was clearly the view of the Operational Requirements Committee (ORC) (a MoD committee founded in 1965) who, according to Jones, advanced a "veritable 'wish list'" of tactical

[134] Zuckerman, (1989), p.389 & p.393
[135] Moore, (2005), p.D.5
[136] Jones, (2)(2017), p.112
[137] Zuckerman, (1989), p.397
[138] Jones, (2)(2017), p.113

nuclear weapons specifically in reference to the need to uphold "the size and content of the programme at AWRE which is decreasing from the end of this year."[139] William Cook, former deputy director of AWRE and now Assistant Chief Scientific Advisor (Projects), advanced the committee's conclusions. In recommending the findings of the ORC to the Chief of the Defence Staff, Cook highlighted how it was also found that work on strategic warheads was needed to maintain the "competence" of AWRE.[140] The new work favoured for this purpose was "generally directed towards a capability by the early 1970's to develop a warhead to replace that in the Polaris system," in addition to completing an initial study of penetration aids.[141]

Although the ORC's report was not the inception of hardening work for Polaris, it was the first move to establish the effort as a full programme and was being suggested as a means by which AWRE could retain skills.[142] Although this confirms the hypothesis that knowledge management concerns were partly behind forwarding Polaris hardening, this was not a sufficient cause. There was an awareness of the growing Soviet Anti-Ballistic Missile capability and a strategic rationale for responding to it; charting the evolution of the technical, strategic and political responses is beyond the scope of this thesis, but it is necessary to highlight how the ORC's initial drive for Polaris hardening was premised on retaining competence at AWRE. Cook would continue to press the Chiefs of Staff in August 1966 to endorse the ORC's findings which featured hardening work to establish a baseline "programme… [that] would be sufficiently attractive to maintain the key scientific and technical skills at AWRE, without which no future capability – thermonuclear, fission, or recertification in Service of current warheads – is possible."[143]

Whatever the strategic rational, Polaris hardening, through Cook's lobbying efforts, had become embroiled within AWRE's running concern over 'uninvention' and the breakdown of the MDA. Such framing was important, as at the first meeting of the Ministerial Committee on Nuclear Policy, held September 1966, the assembled believed that the nuclear deterrent must be maintained to secure American nuclear cooperation on favourable terms to Britain.[144] Hardening was therefore presented (by Cook, the ORC, UKAEA and MoD) in such a way as to be necessary for AWRE, which was needed in order to satisfy the overall policy objectives of the Wilson government. The UKAEA

[139] TNA, DEFE19/197, Future Nuclear Programme - William Cook, 26/06/1966 & Jones, (1)(2017), p.468
[140] TNA, DEFE19/197, Future Nuclear Programme - William Cook, 26/06/1966
[141] Ibid.,
[142] Kate Pyne notes that both the RAE and AWRE studied warhead hardening prior to 1966, with some work readied for Blue Streak. Still classified files indicate that this began in 1957. See TNA, ES1/437 & Pyne, (2004), p.G-3. AWRE's studies on Polaris hardening started in November 1965. Jones, (2)(2017), p.115
[143] TNA, DEFE19/197, Future Nuclear Programme, 02/08/1966, Jones, (1)(2017), p.132
[144] TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 28/09/1966: Although they expressed some doubt considering evolving US policy regarding West German non-proliferation concerns

were even clear about being agnostic towards the direction of the research; any sufficiently challenging work had to be provided or "the quality and momentum of the establishment would rapidly diminish until it ceased to be viable."[145]

Such a conclusion was controversial. The Treasury and the new Department for Economic Affairs predictably placed themselves in opposition to the MoD from 1966-1968.[146] The lack of originality and frustratingly circular logic of arguments in favour of further work premised on tacit knowledge retention were apparent to Treasury officials: Jones quotes an official's letter wherein he complained of being: "back to the old chicken and egg argument" in 1966.[147] Existing warheads had to be maintained by skilled scientists, skilled scientists had to be retained with interesting work, and therefore new projects were always needed even for basic maintenance in an ever ongoing loop. Even the proposed hardening work was acknowledged as a temporary solution that, if conducted promptly, would only serve until the mid-1970s and there were no subsequent plans for further research.[148]AWRE was estimated to account for £167 million over the next ten years, so major reductions were an appealing prospect given the economic turbulence of late 1960s Britain.[149] Given the lack of plans to move beyond Polaris, it is unsurprising that economically orientated officials questioned the logic of protracting this process further and wanted the termination of the nuclear programme as soon as possible.[150] This led to a polarisation between those who were in favour of continuing Britain's nuclear programme and those against: as will be seen, it became a question of avoiding wasteful spending against those who framed it more positively as maintaining the scientific "momentum."[151]

Nevertheless, the case for hardening partially premised on providing a programme for AWRE gained traction from 1966 onwards. Healey embraced these arguments in favour of AWRE and submitted paper ND(66)4 to the NRDC which was largely a replication of prior arguments premised on 'uninvention' (such as ND(62)13), updated to reflect the new preference for hardening.[152] This later led to Zuckerman characterising Healey in his memoirs as having fallen under the influence of

[145] TNA, CAB134/2241, NRDC Nuclear Weapons Development Policy, 07/09/1966. The concept of AWRE relying on 'momentum' was expressed earlier in January 1966 by Richard Way in MoD documents that remain classified. See Jones, (2)(2017), p.113
[146] TNA, CAB164/1093, Inquiry into the Atomic Weapons Research Establishment, 08/01/1968, TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967 & TNA, PREM13/2493, Zuckerman to Prime Minister - Nuclear Issues in the Defence Field, 24/06/1968
[147] Jones, (1)(2017), p.127
[148] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, (n.d.)
[149] Ibid.,
[150] Ibid.,
[151] TNA, CAB134/2241, NRDC Memorandum, 07/09/1966
[152] Ibid.,

"a small but powerful band of civil servants and military men who had a blind faith in anything that was nuclear."[153] While this is true to an extent, Jones highlights that Healey did not accept their arguments uncritically: in terms of ascertaining the true minimum effort required at AWRE, Healey tasked his PUS to establish whether the figures provided were "justified."[154]

The ND(66)4 paper that Healey subsequently endorsed claimed that in order to maintain the MDA and nuclear deterrent, "advanced work … in the thermonuclear field" was required to "retain the number and quality of staff required to maintain AWRE as a viable establishment."[155] In addition, the annex to the paper on 'Manpower and Costs,' attempts to establish a baseline and justification for the minimum manpower required by AWRE. In doing so, it prominently cites ND(62)13 for the lineage of its argument and goes on to reiterate the requirement for a staffing figure of 6000.[156] The paper once again forwards a conception of fragile tacit knowledge being required as "the full spectrum of skills and disciplines… will be required for the military programme in the future."[157] This is further emphasised with its unique and privileged nature: "because of the special nature of nuclear weapons, very little of the expertise necessary exists outside the Weapons Group."[158]

In order to preserve these skills, the paper's annex bluntly states that "the really high calibre staff will be lost unless appropriate new work is injected into the Group's programme."[159] The ND(66)4 paper is also notable for its lack of a technical-strategic justification for developing a hardening capability. A rationale is provided for the retention of a nuclear capability, the means to retain it and cooperation with the Americans, but hardening is presented as being "adequate in American eyes, though no more, to justify continued collaboration and would be attractive enough to maintain the key scientific and technical skills at AWRE."[160] It would therefore not be unfair, in combination with Cook's prior proposal, to conclude that Polaris hardening was initially offered as a solution to a social and diplomatic problem, rather than as a response to Soviet ABM capabilities.

[153] Zuckerman, (1989), p.391
[154] Jones, (2)(2017), p.133 – what the outcome of this enquiry is unknown. The relevant file is classified, and this was conducted before ND(66)4 was submitted, so no significantly contrary evidence was likely returned.
[155] TNA, CAB134/2241, NRDC Memorandum, 07/09/1966
[156] TNA, CAB134/2241, NRDC Memorandum - Annex A, 07/09/1966. This was consistent with the figure provided in 1964 – 6000 was a composite figure of staff for civil and military work. 4300 were projected to be needed on weapons work in the 1970s, but the work on civil diversification was perceived as necessary for the establishment.
[157] Ibid.,
[158] Ibid.,
[159] Ibid.,
[160] TNA, CAB134/2241, NRDC Memorandum, 07/09/1966

A largely unchanged version of the ND(66)4 paper was presented to the Prime Minister in November 1966, and again to the Ministerial Committee on Nuclear Policy in January 1967.[161] However, the time delay between its drafting and its circulation had given a chance for opposition to be formed. The potential for this MoD paper to pass unchallenged apparently spurred Zuckerman into action, as he started to brief sympathetic officials and Ministers against these skill claims.[162] Callaghan, in his role as the Chancellor of the Exchequer, became an outspoken critic of a further commitment to nuclear weapons development as he suggested that new programmes were a "slippery slope in terms of expenditure."[163] Jones notes that in late 1966, Zuckerman was suggesting to Ministers that there was "little point in arguing detail," but that they should question whether the premise of whether the UK should maintain a sophisticated nuclear capability at all.[164] This was perhaps a tactical blunder as it further emphasised AWRE's 'uninvention' argument: the outcome of the January 1967 meeting from Wilson's perspective was that "'on balance' the Committee was in favour of maintaining the capability to work on nuclear weapons, and therefore accepted the programme proposed by the Defence Secretary."[165] At this point, the choice between committing to hardening or abandoning the deterrent was too stark and it appeared that maintaining the status quo was leading.

With the possibility of hardening raised, spring 1967 and early 1968 saw a series of attempts to establish a clear government policy on the future direction of Britain's nuclear weapons programme. For institutions such as the MoD and AWRE, this largely meant trying to establish the strategic and technical needs for a Polaris hardening programme.[166] Key figures such as Penney and Cook attempted to add their "authority" to the Polaris hardening case.[167] These moves conflicted with Zuckerman, the Treasury and the Department of Economic Affairs' attempts to limit such moves.[168] While AWRE was notionally under the Ministry of Technology as part of the UKAEA, they were unable to provide meaningful insight due to their institutional autonomy and sometimes active hostility to oversight.[169] The formulation of a coherent policy was initially limited by these

[161] Jones, (2)(2017), p.163-165
[162] Ibid., p.166-174
[163] Ibid., p. p167 & p.174
[164] Ibid., p.166
[165] Ibid., p.174
[166] Ibid., p.221: This was premised on responding to Soviet ABM. While a full exploration of this theme is beyond the scope of this chapter, it was susceptible to similar dynamics of establishing a minimum level of staffing at AWRE: those most in favour of an ardently pro-nuclear weapons policy were placed in positions to guide technical advice in favour of their chosen course. For instance, Macklen produced a paper in June 1967, predicting that would be reinforced and replicated at several sites across the Union.
[167] Ibid., p.238-239
[168] Ibid., p.201
[169] Ibid., p.278-81

competing factions, but any resolution was dependant on what information the Americans were to provide, commensurate with a British effort.[170] This entailed multiple meetings of the Ministerial Committee on Nuclear Policy in 1967, exchanges by officials and Ministerial visits to Washington and attempts to gauge the future extent of Soviet ABM defences around Moscow. Despite obtaining access to Antelope information and the technical paths forward being presented by Cook in November 1967, the overall deadlock on whether to proceed with Polaris hardening remained.[171] This was only enhanced with the November 1967 devaluation crisis: to the Treasury, this emphasised the need to cut (or at least limit) spending on a capability to which no replacement was planned, whereas for those in favour of hardening, it strengthened the case for a greater indigenous effort to reduce dollar spending.[172]

As the potential technical options became more apparent, the underlying tension between officials, Ministers and departments both for and against a hardening programme remained intractable.[173] As had been the basis for Cook's suggestion for hardening work, the main area of contention was over the future of Aldermaston and its staffing levels. This was raised in a Cabinet review of nuclear weapons policy in August 1967 where the issue of the need to maintain 6000 staff at AWRE came to the fore. As Jones highlights, AWRE's contribution to the review, submitted via the UKAEA and the MinTech "argued… that 'maintenance of a nuclear weapons stockpile requires the same range of resources and skills… as are needed for the original design and production."[174] The dogmatic nature with which the figure of 6000 had been adhered to with an apparent religious degree was noted at the time by financially minded officials.[175] Treasury figures and even some within the MoD and Foreign Office were sceptical and it was reasonable for them to be so; the reasoning for the 6000 figure was not significantly expanded upon.[176] However, as this chapter has noted, the argument that a range of skills were necessary for the maintenance of a capability had been expressed by Levin in 1960, itself stemming from AWRE's historical experiences. The solution, since 1960 (or arguably 1954) had always been a continued programme of work which incorporated advanced research.[177] Cook's role in promoting this solution was clear, with Broadbent noting that

[170] Stoddart, (2012), p.131
[171] Ibid., p.132-133
[172] Jones, (2)(2017), p.242
[173] Ibid., p.274
[174] Ibid., p.278
[175] Ibid., p.279
[176] Ibid., p.279
[177] The ability for Polaris hardening to provide such a programme was questioned at the time as it was presumed the RAE would be doing most of the work, with only a fraction of the budget spent at AWRE. TNA, CAB134/3120, Note by the Chief Scientific Adviser to the Government, 01/12/1967 & Jones, (2)(2017), p.280. Due to AWRE's lobbying, this proved not to be the case and Aldermaston headed much of the work. This has

"CA(P) is perhaps too committed on the extent to which we need to do detailed work at AWRE, and to the view that there is no half-way house in the size of the establishment."[178]

By the end of 1967 there had been no improvement as Ministers and departments became entrenched in either pro or anti hardening stances. According to the Cabinet Secretary, there was however a general "tacit acceptance that, for the present at any rate, we ought to retain… [the Polaris] capability."[179] Nonetheless, in an attempt to gain immediate approval for a hardening effort, Healey once again offered AWRE's views of staffing levels and concerns over uninvention in a Ministerial Committee on Nuclear Policy meeting held on 5th December 1967 .[180] The now familiar line of argumentation expressed by UKAEA documents submitted to the committee stated that in the absence of new work, "key staff would in fact drift away to an extent which would endanger our nuclear capability as a whole."[181]

Given that the nuclear weapons lobby were threatening 'uninvention' and those against at least wanted to impose economies, the emergent consensus in December 1967 was that staffing at AWRE had to be examined in greater detail. As a result of this meeting, the Prime Minister was to arrange for an inquiry, with a rapidly produced draft terms of reference examining the "minimum scale of effort that would be necessary at the Atomic Weapons Establishment."[182] Given that Wilson's "sympathies might be found to lie with the Chancellor," it was suggested that the inquiry proceed in two phases.[183] As the second phase was intended to identify economies, it somewhat presupposed the findings of the first phase on establishing the minimum scale of effort would be significantly below the current strength; in this regard, the inquiry would prove a disappointment.[184]

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been cited as the major cause of the cost overruns and delays to the Chevaline. Mcintosh, (1990), p.104, Jones, (2)(2017), p.280

[178] TNA, DEFE13/544, Nuclear Policy, 16/10/1967

[179] TNA, CAB168/25, Nuclear Policy - Trend to Prime Minister, 04/01/1968

[180] Stoddart, (2012), p.137, Jones, (2)(2017), p.332, TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 05/12/1967

[181] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967

[182] TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 05/12/1967 & Jones, (2)(2017), p.332-333

[183] TNA, CAB168/25, Nuclear Policy - Trend to Prime Minister, 04/01/1968 & Jones, (2)(2017), p.333

[184] In the event, this second stage never happened, but there were calls for it to be initiated even before the 1st stage had reported. TNA, PREM13/2493, Zuckerman to Prime Minister - Nuclear Issues in the Defence Field, 24/06/1968

Kings Norton Inquiry: Oversight and AWRE

As it took time for the composition and terms of the inquiry to be finalised, the exact formulation was only agreed on 28th February 1968.[185] One of the elements that had incurred the delay had been selecting mutually acceptable panel members that would be sufficiently qualified, but who would also be UKAEA outsiders. [186] While possessing considerable defence, business and leadership experience, none of the final members were intimately familiar with nuclear weapons research and development.[187]

Given an approximate three month time frame to produce results, the first meeting of the panel was held on 11th April 1968 and reported on the 31st July 1968.[188] Cabinet papers from June 1968 highlighted that the desired outcome of the Inquiry was to "i) give… an estimate of the full cost of AWRE… ii) express… whether AWRE is… to remain viable [if confined to maintenance] … iii) … whether… reducing expenditure … at AWRE [is possible] if the military task is restricted to maintaining existing weapons."[189] While it was able to present a figure for the first point, the first conclusion of the report was that "it will be necessary to retain the strength of professional staff at close to the present level" if even only a maintenance role was intended for AWRE.[190] With its inability to identify savings beyond a marginal reduction in support staff, the report failed to substantially satisfy either the pro or anti-hardening aligned institutions (perhaps with the exception of AWRE).[191] The findings were divisive enough even amongst its panel members to produce a minority report penned by Lord Rothschild.[192] While he went beyond the terms of the inquiry to argue against the strategic rationale of even the Polaris programme, he also took issue with the way in which the panel determined the 'minimum effort' required at AWRE.[193] Despite cabinet

[185] TNA, DEFE13/925, AWB to Prime Minister - Enquiry into AWRE, 26/02/1968 & Jones, (2)(2017), p.362
[186] Jones, (2)(2017), p.332
[187] While Lord Carron was a member of the UKAEA executive, he was from a trade union background. TNA, DEFE13/925, AWB to Prime Minister - Enquiry into AWRE, 26/02/1968. Zuckerman had suggested former Harwell scientists for the panel, but this was apparently not adopted - TNA, CAB168/8, Zuckerman to Trend, 15/01/1968. Technical experience was presumably reserved for the tentative 2nd stage. James Taylor was the most technically minded, having had a distinguished chemistry career at ICI before becoming the deputy chairman for the ROFs board. Jones, (2)(2017), p.363 & Taylor, (1961)
[188] TNA, DEFE13/925, Cabinet Committee on Nuclear Policy - Atomic Weapons Establishments, (n.d.)
[189] TNA, CAB168/25, Lawrence-Wilson to Zuckerman, 13/06/1968
[190] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968
[191] Jones, (2)(2017), p.424 & TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968
[192] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Minority Report, 07/1968
[193] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Appendix XII, 07/1968

differences and attempts to restrict the circulation of the report, the agreed interpretation presented by the SofS and the Minister of Technology was for a reduction in staff from 6300 to 5600 by 1975.[194] Even this figure represented the upper bound of the minimum required according to the inquiry, and "would [fall] mainly among the support staff; there would be little change in… professional staff."[195]

Uninvention

The fundamental reason for the criticism levelled at the report was their inability to progress beyond the 'uninvention' argument offered by AWRE from 1960 onwards. This meant that the panel could only recommend superficial reductions to support staff. The fragility of special skills and the need to retain research momentum was once again used to threaten 'uninvention' of the nuclear capability and therefore reject economies. These arguments are advanced early in the report, where a new maximalist version was presented: The panel was satisfied "that nuclear weapons work is fundamentally different from other kinds of defence work because the consequences of failure or error are of a completely different order of magnitude."[196] This formulation granted nuclear weapons a special privilege that further limited enquiry. As a result of this modality, the panel "accept[ed] that the maximum safety and reliability must be preserved at all stages of the nuclear weapons programme including the maintenance of the stockpile. This requires the retention of high quality scientific and technological staff, and much complex capital equipment."[197] The extent to which the panel embraced this argument appears to have surprised Macklen who noted that "they seemed to be very impressed by the need for great care in this work."[198] Even in the event that AWRE was reduced to a maintenance only role, the panel concluded that the "complex and demanding nature of the work which could arise… [would be] as challenging as the original development."[199] Therefore, unless the nuclear deterrent was abandoned (which was beyond the remit of the Kings Norton Inquiry to consider), "it will be necessary to retain the strength of

[194] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy Meeting Minutes, 20/12/1968
[195] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy – Note by the Secretary of State for Defence and the Minister of Technology, 05/12/1968, TNA, DEFE13/925, Cabinet Committee on Nuclear Policy - Atomic Weapons Establishments, (n.d.)
[196] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968
[197] Ibid.,
[198] TNA, DEFE13/925, V. Macklen to CA(PR), 26/07/1968
[199] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968

professional staff at close to the present level."[200] Although a minor reduction in the level of support staff was countenanced, this logic effectively precluded any reductions at AWRE below the then current level.[201]

The logic for this argumentation was reportedly provided by the "Director of Aldermaston" according to the Rothschild minority report.[202] Given its reported origin from the nuclear establishment, it is unsurprising that the wording of the Kings Norton Inquiry's initial section is strikingly similar to the December 1967 UKAEA's annex within the Defence Review Working Party's Report.[203] This suggests that the panel accepted AWRE's views without significant caveats and that the UKAEA's annex within the Defence Review Working Party can be used to provide further context to the AWRE's perspective in the period surrounding the inquiry. The annex from the 1967 paper suggested that "the serviceability, life and safety of the weapon can only be assessed by staff with experience of nuclear weapon design."[204] It was claimed that this assertion was based on AWRE's prior experience in maintaining warheads. [205] However, due to the unpredictability of this process, it was allegedly "impossible to predict by how much" various different skills embodied within individuals would be utilised in the "peculiarly complex and demanding tasks."[206]

As these arguments had been accepted, the possibility for suggesting economies amongst the professional grades had apparently been ruled out from the outset because of tacit knowledge-based arguments from AWRE. As evidenced in this instance, these arguments are difficult to challenge as they allegedly stem from individuals' non-communicable expertise. The inability of the inquiry to progress beyond this difficulty was highlighted from the outset; the report states that "it would not be feasible to examine the Weapons Group estimate of staff needs in detail without many months of continuous work. We have, however, been able to arrive at broad judgements which we consider sufficient to fulfil our remit."[207] Given this was one of the supposed purposes of the inquiry, it is unsurprising that this elusion proved to be highly controversial. Lord Rothschild's minority report also took issue with this stance, but concurred that it could only be resolved with "a whole-time investigation which would take many months."[208] The acceptance of a tacit knowledge based

[200] Ibid.,
[201] Ibid.,
[202] Currently, Edward ('Ted') Frank Newley.
[203] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967
[204] Ibid.,
[205] Ibid.,
[206] Ibid.,
[207] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968
[208] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968 & TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Minority Report, 07/1968

argument by the majority panel and the existence of Rothschild's report suggested to the "suspicion of some in Whitehall that the Committee had swallowed the AWRE argument, based entirely on statements presented by Aldermaston scientists."[209] According to Zuckerman, the panel "immediately decided it could not… [enquire deeper into the estimated staff levels]… in the time available. As a result, Ministers are now presented with a white-washing report which carries them little further than they were at the start of the enquiry." [210] Even the Defence Secretariat thought that the Kings Norton Inquiry provided "admittedly no more than a superficial judgement," and could potentially be cited to block reasonable reductions.[211]

Even for Macklen, often characterised as a consistently pro-nuclear partisan, supported the premise of the argument but was more determined to find efficiencies. He recommended further staffing reductions, but was careful to couch his suggestions as "opinion" and "personal views."[212] No evidence or justification is provided for these further reductions and while the figures he provides are not elaborated upon in terms of the grades of staff that could be made redundant, his economies entailed closing AWRE outstations and presumably a 500 reduction from support staff at Aldermaston.[213] Nevertheless, Macklen's more immediate reaction to the report in July 1968 was that its "value… is perhaps reduced by the fact that it takes a much more extreme view than is realistic about the need to maintain the capability and the size of the present resources."[214]

Although Zuckerman, Macklen and others were unhappy with the inquiry and that the panel thought they had not been granted enough time, what is notably lacking from their criticism is any suggestions for an improved methodology to find a satisfying answer. As highlighted by the majority's response to the Rothschild report, the determination of an acceptable level of staffing should be continually revised as "the future situation in this field cannot be known with certainty."[215] This also meant, that as far as the panel and AWRE were concerned, no determination could be made at the present as the technical challenges that would be faced would remain unknown until encountered. If this logic is accepted, it is difficult to see when these conditions would ever resolve themselves, thereby making any significant reductions impossible. Progressing beyond the argument

[209] Walker, (2010), p.313
[210] TNA, DEFE13/925, Atomic Weapons Establishments - PN(68)9, 19/12/1968 & TNA, PREM13/2493, Zuckerman to Prime Minister - AWRE Report, 12/09/1968
[211] TNA, DEFE13/925, Kings Norton Report - Costing Aspect, (n.d.)
[212] TNA, DEFE13/925, Kings Norton Report - Money and Manpower at UK Nuclear Weapons Establishments - Brief prepared by ACSA(SN), (n.d.)
[213] Ibid.,
[214] TNA, DEFE13/925, V. Macklen to CA(PR), 26/07/1968 & Jones, (2)(2017), p.419
[215] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy – Note by the Secretary of State for Defence and the Minister of Technology, 05/12/1968

as presented by AWRE was challenging as the Defence Secretariat admitted that "we here have very little information to go on" to counter the assertions made in the inquiry.[216] Whatever the sincerity of the argument as presented by AWRE, there was a view within the MoD that they "have tried to concede as little as they felt they could get away with."[217] Given the opacity of AWRE, the autonomy of the UKAEA, the sense of an argument of authority derived from tacit knowledge, a speculative proposition on the future of nuclear weapons maintenance and a divide between practitioners and those intended to provide oversight, it is unsurprising that the argument could not be overturned or easily dismissed.

Diversification

If the need to maintain a large cohort of staff to preserve a nuclear capability was unpalatable, the implications were even more unsettling for those who wanted to impose stringent reductions on the nuclear programme. The consistent argument from Aldermaston from 1954 was that if staff were to be retained, they must be encouraged to remain with a diversified research portfolio.[218] As seen, efforts to expand non-nuclear research had been steadily increasing after 1962, with the introduction of non-nuclear civil work after 1964.[219] By 1968, diversified work was employing approximately 1700 of the 6175 Aldermaston employees, but a 1967 Overseas Policy and Defence Official Committee paper noted that this transition had been done "with difficulty."[220] Rothschild and Zuckerman were highly critical of diversification; if the purpose of the work was to retain scientists then they contended that 22% of AWRE's operating costs were being used on "make weight" work to "keep the scientists happy."[221] Rothschild's question of "how much is the country prepared to pay to keep these experts happy" had some weight since £5.4 million was being spent on these efforts in a period of economic instability.[222]

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[216] TNA, DEFE13/925, Kings Norton Report - Costing Aspect, (n.d.)
[217] TNA, DEFE13/925, AWRE: Kings Norton Report and Rothschild Minority Report, 10/09/1968
[218] See Chapter 5
[219] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment - Appendix V, 07/1968 notes that "the introduction of non-nuclear work into the Weapons Group was first considered in 1962 as a result of a sharp cut in the nuclear weapons programme."
[220] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Minority Report, 07/1968 & TNA, CAB148/55, OPDO Meeting Minutes, 08/09/1967
[221] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Appendix XII, 07/1968 & TNA, PREM13/2493, Zuckerman to Prime Minister - AWRE Report, 12/09/1968
[222] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Minority Report, 07/1968

Rothschild and Zuckerman were especially critical of diversification as they perceived that Aldermaston was not an efficient place to conduct civil research when compared to Harwell; intense security and a lack of a profit orientated model were cited as the foundation of their inherent inefficiency.[223] This was strenuously denied by the UKAEA who claimed that such insinuations were "unfounded" and the work was done in "the national interest."[224] Macklen provided the example of nuclear test monitoring, fast breeder reactor research and nuclear forensics work which were done economically at AWRE and would be done anyway, "independent of nuclear weapons work."[225] Nonetheless, he questioned "does it now matter that AWRE… is used for many other purposes; is this not just a normal process of time changing roles. This is not the first Establishment, Organisation, or Office which only spends half its effort on its original task."[226] This was somewhat contradicted by the Minister for Technology who believed that "other work had to be given to… staff which was of relatively low priority and which would perhaps be more suitably carried out in industry."[227] Therefore the suggestion that diversification came at no cost to the Exchequer by the Kings Norton Inquiry was questionable.[228] There was however general agreement (including from the Kings Norton panel) that further relevant diversified defence work could be found by consolidating other government defence establishments and apportioning some of the work to AWRE.[229] Nonetheless, if a major weapons research programme was not provided, the logic of the UKAEA's arguments was that more money would have to be spent on diversification in compensation.

Spare Capacity

While diversified non-nuclear weapons work was a way of retaining staff at AWRE, it had been increasingly suggested since 1962 that this was insufficient; some advanced nuclear weapons

[223] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Minority Report, 07/1968 & TNA, DEFE13/925, Further Comments on Minority Report, 30/08/1968
[224] TNA, DEFE13/925, Notes by the UKAEA on the Majority and Minority Reports of the Working Party on Atomic Weapons Establishments, 30/08/1968 & TNA, DEFE13/925, Future of Atomic Weapons Research Establishment - note by officials of MinTech, MoD and the UKAEA, (n.d.)
[225] TNA, DEFE13/925, Lord Rothschild's Report: Technical Aspects, (n.d.)
[226] Ibid.,
[227] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy Meeting Minutes, 20/12/1968
[228] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy – Note by the Secretary of State for Defence and the Minister of Technology, 05/12/1968
[229] TNA, DEFE13/925, Lord Rothschild's Report: Technical Aspects, (n.d.), TNA, DEFE13/925, Atomic Weapons Establishments - PN(68)9, 19/12/1968 & TNA, CAB134/3121, Ministerial Committee on Nuclear Policy Meeting Minutes, 20/12/1968

research programme was inherently necessary.[230] As argued, this was the initial impetus for Cook bringing the possibility of Polaris hardening work to the fore in 1966. This argument was reiterated by the UKAEA in 1967 and again in 1968.[231] The remit for the Kings Norton Inquiry also reinforced this supposition as its remit was based on the overarching concern that the ability to retain nuclear weapons capability was to be upheld. Maintenance required the upkeep of a suitable establishment with the skilled individuals it employed. These staff members were to be retained on the basis that they would be required for challenging maintenance issues. If staff levels were kept at the 6000 level as proposed by the AWRE and the UKAEA, there would have to be a radical increase in diversified work; with no major addition of work, one sixth of the capacity of AWRE would be unutilised from 1972 onwards.[232]

Had the Kings Norton Inquiry been able to recommend reductions significantly below the 6000 figure (especially among white paper grades), then logically the demands for work to fill spare capacity would reduce, thereby nullifying this justification for the Polaris improvements as diversified work and stockpile maintenance could provide a more sustainable programme. Even if this were to happen, it was still argued that only nuclear weapons research was seen to provide the "sufficient challenge" that would maintain "interest and morale."[233] The clear contender being forwarded to fill this void was "the full programme of Polaris hardening [which] would provide the necessary challenge and stimulus [to AWRE]."[234] In 1967 it had been alleged that without such a programme, its absence "would imperil the whole technical capability of AWRE."[235]

Although not privy to the full technical and strategic insights of the PRESSG report, the logic of finding challenging work meant that the panel "[felt] that the first preference in selecting additional work to utilise this capacity should be military nuclear work."[236] Given their remit to consider hardening and the lack of other contenders, this was a clear endorsement for using the 'spare capacity' for Polaris improvements.[237] This was affirmed by the Minister for Technology and the SofS, who declared that "if we decide on anything less than an advance programme of

[230] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962
[231] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967
[232] Ibid.,
[233] Ibid.,
[234] Ibid.,
[235] Ibid.,
[236] Ibid.,
[237] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy – Note by the Secretary of State for Defence and the Minister of Technology, 05/12/1968 & TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968

improvement, spare capacity at AWRE will rise sharply."[238] To nuclear weapons sceptics, the need to constantly develop new technologies to even maintain present capabilities was unacceptable. The above logic was criticised by Rothschild as pledging the UK to an "open-ended financial commitment," which was not unfair, given that the report acknowledged that the UK would also have to find further nuclear weapons work beyond 1975.[239] Cook and Macklen's response was that "all R&D is to some extent open ended;" this serves to highlight the polarisation between those in Whitehall who thought that the expenditure was worthwhile, compared to those in favour of nuclear disarmament.[240]

A logical extension of the argument for hardening premised on retention of skills was that any new system would have to be developed in the UK, rather than bought from the US, even if this would prove the better value proposition. This was for two reasons: firstly, if the intention of hardening was to fill the 'spare capacity' gap, then a bought system would provide no benefit.[241] In addition to highlighting savings for reducing US dollar expenditure, the Kings Norton panel also framed the benefits of indigenous production in terms of tacit knowledge: "where a new field of technology such as hardening is concerned, Weapons Group does not [sic] gain real technological understanding if a U.S. system is adopted."[242] Once again, while not couched in present terminology, this was a clear appeal for the need to accrue relevant tacit knowledge by working on their own system.

Morale problems?

In terms of continuity of arguments from 1962, the role of staff morale was minimised. Whereas Conservative promises made to the establishment in the 1950s created the expectation amongst staff of secure employment, the gradual reduction in staffing from 1962 and Labour's nuclear sceptic campaigning prior to 1964 meant there was no such belief.[243] Nonetheless, this did

[238] TNA, CAB134/3121, Ministerial Committee on Nuclear Policy – Note by the Secretary of State for Defence and the Minister of Technology, 05/12/1968 - although it was recognised that this would occur again after the completion of the effort in 1975
[239] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Appendix XII, 07/1968
[240] TNA, DEFE13/925, Lord Rothschild's Report: Technical Aspects, (n.d.)
[241] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967
[242] Ibid.,
[243] Although this may have implicitly contributed to the demand of securing 'interesting' work into the future.

not prevent the UKAEA briefly highlighting in their contribution to the Defence Review Working Party in 1967 that "a large number of staff… have in the past received repeated assurances of continued employment."[244] Although the argument for retention of staff was predicated on suggesting that they would leave without a further programme, little attention was given to assessing morale.[245] The Kings Norton panel cited "representations from the Staff Side of the Whitley Council that the long period of uncertainty about the future of the Weapons Group, dating back to 1962, has brought an undesirable state of low morale."[246] Somewhat contradictorily, in a follow up meeting between the Minister of Technology and Kings Norton, Kings Norton highlighted that he had only seen "some anxiety… and he would imagine they would continue to speculate about their future. Morale among the industrial staff had seemed to him to be excellent."[247] Rather than more systematically inquiring as to the state of morale at the establishment, Zuckerman instead insisted that "make-weight" diversified work reduced confidence in AWRE's future.[248]

That no attempt was made to more accurately survey morale at AWRE is surprising, given that morale had been cited repeatedly by AWRE in relation to attempts to change policy in the past.[249] While officials suggested the need for further work to ensure retention, evidence for the then current state of morale at AWRE was anecdotal. The previous chapters have seen the detailed attention given to housing, amenities and wages in order to recruit and retain staff, but specific discussion of staff concerns are notably lacking from Cabinet papers and the Kings Norton Inquiry.[250] Given that the proposition of the UKAEA was that the most skilled scientists could only be retained if their "interest and enthusiasm" was kept through new, challenging and diverse work, not examining their present conditions or ability to retain them with remedies other than with (or in combination with) new projects appears to be an oversight.[251] As this argument was sometimes leveraged to

[244] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967
[245] TNA, CAB148/55, OPDO Meeting Minutes, 08/09/1967
[246] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968
[247] TNA, DEFE13/925, Summary of a Meeting Between the Minister of Technology and Lord Kings Norton, 20/02/1969
[248] TNA, PREM13/2493, Zuckerman to Prime Minister - AWRE Report, 12/09/1968 & TNA, DEFE13/925, Atomic Weapons Establishments - PN(68)9, 19/12/1968
[249] See previous chapters.
[250] For example, these concerns are not in TNA, AB16/2303, Ministry for Science Working Party – Staff and Facilities Available in the Weapons Group, 22/11/1962 or TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962
[251] TNA, CAB168/8, Untitled Draft [Terms of Reference of Kings Norton Inquiry], (n.d.), TNA, CAB134/3121, Ministerial Committee on Nuclear Policy – Note by the Secretary of State for Defence and the Minister of Technology, 05/12/1968, TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party (and Appendix V), (n.d.),

justify expressly military projects (rather than civil diversified research, as only military work would do), it does leave questions over the internal logic of the argument.[252]

Mutual Defence Agreement

The use of the Mutual Defence Agreement in justifying staffing at AWRE to Ministers appears to have diminished in the Kings Norton Inquiry, compared to 1962.[253] Discussion of the MDA and American cooperation appears briefly in the third annex of the Kings Norton Inquiry report.[254] While cooperation with the United States was still essential for the maintenance of Polaris, the value of further exchanges was dependant on whether the UK continued nuclear weapons development.[255] This was contingent on a political decision from a Labour government which was hesitant to commit to such moves.[256] This confusion was compounded by the extent to which the UK would potentially upgrade its Polaris systems being dependent upon information it gained from the US to determine the viability (and cost) of particular approaches; although this information was increasingly available from 1967, obtaining it proved a protracted process.[257] Therefore, while the Kings Norton Inquiry noted that further collaboration with the United State was dependant on the UK providing "a real contribution," which was presumed to be "further weapon development," the issue of the MDA was subsumed into a wider debate over foreign policy, disarmament and the

[252] This argument was also expressly used in 1967 to justify the need to retain Polaris, otherwise, the lack of challenging work would mean the loss of the "nucleus" of the technical staff which in turn would mean that "the viability of the establishment as a whole would rapidly decline." - TNA, CAB164/1093, Inquiry into the Atomic Weapons Research Establishment, 08/01/1968.

[253] This is somewhat surprising given that the agreement was up for its 10-year renewal in 1969. However, Zuckerman strongly advised Wilson that the possibility that the Americans would not terminate the agreement in its entirety whatever decision was made on hardening but would refuse to provide 'new' information. November 1968. TNA, CAB168/25, Zuckerman to Prime Minister, 28/11/1968. The MDA was perceived as highly important to the nuclear establishment by AWRE officials, but it was not used prominently to justify a further programme to Ministers.

[254] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968

[255] This was recognised by the first meeting of the Ministerial Committee on Nuclear Policy of the Wilson administration on 28th September 1966. TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 28/09/1966

[256] TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 03/04/1967 & TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967

[257] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party, 01/12/1967, TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 03/04/1967, TNA, PREM13/2493, Zuckerman to Prime Minister - Nuclear Issues in the Defence Field, 24/06/1968 & Pyne, (2004), p.G-8, TNA, PREM13/2493, Zuckerman to Prime Minister - Nuclear Issues in the Defence Field, 24/06/1968 & TNA, CAB168/27, Improvements of the Polaris System - Artificer, (n.d.)

future viability of the nuclear weapons establishment.[258] The role of the MDA in staffing levels and future nuclear policy was perhaps dictated earlier in 1966, when Cook and other MoD officials had argued that tactical nuclear weapon work alone would "not suffice to maintain AWRE at a level of competence and activity that will give us continued access on an exchange basis to American information."[259]

Kings Norton: Oversight Failure?

Many contemporaries viewed the Kings Norton Inquiry as a failure, despite its eventual acceptance by Ministers in December 1968. It proved unsuitable for providing justification for meaningful savings at AWRE, which was the motivation for its initiation.[260] As a result, the report did not serve to break the Cabinet deadlock as it had been hoped, so decisions on the future of the nuclear programme were further deferred.[261] Inaction on what the future of AWRE should be was delayed pending receiving the PRESSG report, a wider restructuring of the twenty three government research establishments and the UKAEA, the ongoing SALT talks and the upcoming US presidential elections.[262]

Given the apparent acceptance of long developed arguments forwarded by AWRE, the inquiry failed to provide further insight into establishing a 'minimum effort.' Zuckerman bluntly stated that "the Kings Norton report uses the AWRE claims to justify continuation of the status quo [sic]."[263] This is accurate given the panels initial acceptance that "maximum safety and reliability must be preserved at all stages," and when combined with the panel deciding not to explore AWRE's staff estimates, these decisions limited its ability to contradict AWRE from the outset.[264] This was only reinforced by the lack of a serious attempt to quantitatively or qualitatively gauge morale or staff retention efforts beyond simple enquiries to AWRE's Whitley council. As a result, it is not unfair

[258] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968. & Jones, (2)(2017), p.431-432
[259] TNA, DEFE19/197, Future Nuclear Programme - William Cook, 26/06/1966 & TNA, CAB134/2241, NRDC Memorandum - Annex A, 07/09/1966
[260] Jones, (2)(2017), p.421, p.428-429 & p.474 and Walker, (2010), p.313
[261] TNA, CAB168/25, Nuclear Policy - Prime Minister to Secretary of State for Defence, 26/06/1968, TNA, PREM13/2493, Zuckerman to Prime Minister - Nuclear Issues in the Defence Field, 24/06/1968 & Moore, (2004), p.D-9
[262] Gummett, (1980), p.126-127, Stoddart, (2012), p.140 & Jones, (2)(2017), p.474-477
[263] TNA, PREM13/2493, Zuckerman to Prime Minister - AWRE Report, 12/09/1968
[264] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968

that Moore characterises the inquiry as presenting "fairly bland conclusions."[265] On the other hand, Stoddart characterises the Cabinet's acceptance on the inquiry's findings as a "turning point in working-level British nuclear weapons policy," as it eventually enabled what would become Chevaline.[266]

Both representations do not fully capture the reality of the outcome of the inquiry. What the Kings Norton Inquiry represented was the greatest external scrutiny that the nuclear weapons establishment had, until that moment, ever been subject to. Given the unilateralist tendency of some of the Labour Cabinet and the intense pressure to impose savings, it was perhaps the greatest existential threat faced by AWRE since Tizard's attempt to cancel the HER programme in 1949-1950.[267] However, apart from Rothschild, the inquiry accepted the tacit knowledge arguments presented to them by AWRE without alteration. Whether this was an endorsement of AWRE's arguments or an incapability for those external to the programme and without the prerequisite technical knowledge and security clearances to provide meaningful oversight is difficult to say. With the panel's inability to examine staffing figures provided by AWRE in the time available (and no suggested method to do so even if more time were given), limitations on the technical information available to them and acceptance of speculative arguments based on the future retention of staff and the arsenal without substantive evidence, it strongly suggests an inability to do so. In a September 1968 letter to the Prime Minister, Zuckerman summarised this criticism as follows: "[the panel] accepted the highly dubious statement that the maintenance of a stockpile of nuclear weapons necessitated as highly skilled a scientific and technological staff as was required to design and engineer such weapons in the first instance."[268] Without better options, given with what Zuckerman perceived as the inquiry's failure, he suggested that "Ministers… impose an immediate arbitrary cut in the annual budget of nuclear weapons work at AWRE… of the order of 20 per cent would enforce that reassessment of staff structure which no one outside the establishment has yet been able (or willing) to carry out."[269] While not conducted, the fact that control and oversight over AWRE had been reduced to this extent is notable. Even when recommending the inquiry's findings, officials from the MoD, MinTech & UKAEA said that there were "no grounds for doubting" the need for the current level of staff, but no further affirmative defence of the finding was issued.[270] This

[265] Moore, (2004), p.D-8
[266] Stoddart, (2012), p.231
[267] The cuts imposed on AWRE from 1962 aside.
[268] TNA, PREM13/2493, Zuckerman to Prime Minister - AWRE Report, 12/09/1968
[269] Ibid., Zuckerman reiterated this call at the Ministerial Committee on Nuclear Policy meeting on 20th December 1968. TNA, CAB134/3121, Ministerial Committee on Nuclear Policy Meeting Minutes, 20/12/1968
[270] TNA, DEFE13/925, Future of Atomic Weapons Research Establishment - note by officials of MinTech, MoD and the UKAEA, (n.d.)

raises the question: who, other than those intimately involved in the production of nuclear weapons (and therefore from AWRE), was in an authoritative position to dispute staffing requirements? The answer appears to be no one.

The inability for external parties to overcome this challenge despite their scepticism over AWRE's claims is unsurprising. As highlighted in previous chapters, Sims and Henke have observed how tacit knowledge-based arguments have been useful rhetorical devices to post-Cold War nuclear weapons establishments, effectively used to justify further resources.[271] This thesis has traced how AWRE developed a conception of skill that it then expressed to policy makers. Their argument shared the essential elements of Polanyi's conception of tacit knowledge, which was then articulated by MacKenzie and Spinardi and used by nuclear weapons establishments in the 1990s. The ongoing rhetorical potency of the argument in its various iterations can be attributed to how Polanyi's conception of personal knowledge was "developed as the cornerstone argument in a principled rejection of the very idea of managing the production of scientific knowledge."[272] The independent conception of a similar logic by AWRE through its historical experiences does not diminish how it was used to the same effect in the Kings Norton Inquiry. The argument was premised on identity and authority (as 'weaponeers') to which external parties had little hope of matching. This is not to dismiss the accuracy or sincerity of the argument; as will be seen, there was a reality to maintaining the necessary skills in the establishment, but it instead highlights how it was utilised and the difficulty in scrutinising its claims.[273]

Oversight and Autonomy

Therefore, what the Kings Norton Inquiry represented was the inability of parties outside of AWRE to provide meaningful oversight over the nuclear weapons programme. Although this mechanism was hypothesised in the framework, this failure was fundamentally a product of the argument used by AWRE, premised on epistemological authority and enhanced by institutional secrecy. This thesis already noted the repeated inability of the treasury to provide insight into what constituted reasonable spending at the weapons establishment. This continued throughout the 1960s and was a source of frustration to Wilson, even after the Kings Norton Inquiry, as he "expressed his dissatisfaction with the situation… [that] the Treasury… seemed incapable of subjecting the demands of organisations such as AWRE to the same exhaustive scrutiny as was

[271] Ibid.,
[272] Schmidt, (2012), p.173
[273] The potential reality of uninvention will be covered in the next chapter.

devoted to relatively minor and detailed matters in certain departments."[274] The institutional autonomy provided by the UKAEA separated AWRE from the same review mechanisms as other government departments.[275] Oversight over AWRE was meant to be provided by the MinTech, but their officials were frequently denied technical and financial information; according to "Dennis Fakley, deputy chief scientist at the Ministry of Defence at the time: 'From the point of view of the nuclear weapons programme, MinTech was an irrelevance.'"[276] The official secrecy surrounding the nuclear weapons establishment was rigidly maintained by MoD officials who created a virtual "monopoly of knowledge over the field of nuclear policy."[277] Visits to AWRE by officials from other departments were only "reluctant[ly]" facilitated by the MoD.[278] Zuckerman observed that reluctance to share information helped preserve the inscrutability of nuclear weapons, as "the Aldermaston scientists worked in strict secrecy on mysteries which the ordinary civil servant or politician could not begin to understand."[279]

This process extended to a wider culture that limited the distribution of papers; this "skulduggery" most notably included preventing access to both the findings of the Kings Norton Inquiry and PRESSG papers to Ministers.[280] The denial of technical information was perceived as "a deliberate attempt within the Ministry of Defence to at best delay for a long time and at worst sabotage… the AWRE enquiry."[281] The situation was so dysfunctional that according to Jones, the Cabinet Office "hoped to put a 'ferret' into the MoD" to discover if they were intentionally withholding information.[282] With Zuckerman outside of the MoD after 1966, the provision of technical information to government and the inquiry was left to individuals such as Cook, Macklen and Newley.[283] Contemporaries such as Zuckerman and later academics such as Spinardi and McLean & Beyer noted that this was unlikely to result in impartiality when the officials involved all "instinctively shared Aldermaston's aspirations."[284] Zuckerman still played an influential role as CSA

[274] TNA, PREM13/2493, Note for the Record – marked 37, (n.d.), also cited by Walker, (2010), p.314 and Jones, (2)(2017), p.424
[275] TNA, PREM13/2493, Note for the Record – marked 33, (n.d.)
[276] Adams, (2011), 672.0/1404, Jones, (2)(2017), p.112-113, p.278-81 & p.472. The role of the MinTech was fulfilled by the Ministry of Aviation prior to 1967.
[277] Jones, (2)(2017), p.264-265. This held true both for the minimum level of work at Aldermaston, but also the technical challenge and possible responses to Soviet ABM systems. See Jones, (2)(2017), p.539-540
[278] Ibid., p.264
[279] Zuckerman, (1989), p.386
[280] Moore, (2004), p.D-3
[281] TNA, PREM13/2493, The Enquiry into AWRE - Trend to Prime Minister, 29/05/1968
[282] Jones, (2)(2017), p.387
[283] Stoddart, (2012), p.131
[284] Zuckerman, (1989), p.391, Spinardi, (1997), p.574 & McLean and Beyer, (1987), p.148. In contrast to 1962, the UKAEA chairman, Sir John Hill provided information on reductions to Zuckerman, including that the Orfordness outstation had "200 people are engaged doing practically nothing." TNA, CAB168/8, Zuckerman to Prime Minister, 18/09/1968

to the Cabinet Office and continued to oppose a hardening programme with an "intermittent rear guard action," but did so with limited insight and authority.[285] Even after the change of government in 1970, the established dynamic of Cook and Macklen providing information favourable to a hardening programme, with Zuckerman playing his role as the sceptic would continue.[286] According to correspondence received by Walker, "Zuckerman had initiated this enquiry with the aim of emasculating AWRE" in 1968.[287] While perhaps one of few options left to significantly diminish AWRE, it was unlikely to succeed. With no external party qualified to oversee the provision of advice regarding skills and staff retention at AWRE, it is unsurprising the inquiry made no more headway in 1968 than the collective organs of government had done between 1966 and 1968.

Results

Given the delays in decision making in the last two years of the Wilson administration, the Kings Norton Inquiry was the last major impetus for economies to be imposed on AWRE. The report had suggested the need for hardening work because of spare capacity, but this was not committed to. The Labour government of 1966-1970 never positively affirmed that a Polaris hardening programme should take place; the "continually and intentionally delayed" PRESSG report recommended that a feasibility and definition study should take place when it was finally made available in March 1970, but this was only approved of by the incoming Conservative government in October 1970.[288] Nonetheless, due to the lack of oversight and autonomy afforded to the weapons establishment, "bureaucratic momentum" continued to be accumulated in regards to Polaris hardening.[289] AWRE were able to expand the resources available to the endeavour through its 'self-initiated research' budget.[290] By 1969, AWRE were already spending "£3.5 million per annum" on Polaris hardening on the grounds of testing "feasibility."[291] This would rise to £4 million per year by 1970, meaning that a considerable amount of money had been spent on Polaris hardening before any decisions beyond exploratory research had been made.[292] Zuckerman was already complaining

[285] TNA, CAB134/3120, Note by the Chief Scientific Adviser to the Government, 01/12/1967 & Jones, (2)(2017), p.536
[286] TNA, CAB168/27, Press to Zuckerman, 30/09/1970
[287] Walker, (2010), p.313
[288] Jones, (2)(2017), p.536, Walker, (2010), p.318 & Pyne, (2004), p.G-8
[289] McLean and Beyer, (1987), p.149
[290] Pyne, (2004), p.G-8
[291] Jones, (2)(2017), p.515
[292] Stoddart, (2012), p.140

in 1968 that "although AWRE had had no new programmes since the present Government came into office, they had nevertheless spent around one million pounds annually on capital equipment."[293] This momentum was not only monetary, but also diplomatic; Polaris hardening involved extensive negotiations with the Americans for information which peaked with the covert UK participation in radiation tests in Nevada for nominal payments.[294] Terminating the programme abruptly would have been a humiliating volte-face. Although yet to be convinced of the strategic case for Polaris hardening, the Wilson governments attempt at keeping "options open" was proving highly expensive.[295] The existence of the programme became self-justifying on the basis of continuing research at AWRE and sunken costs.[296] This continued into the Heath administration where a 1973 document exploring options for improving Polaris where an indigenous programme, on "which a considerable amount of money has been spent," was the only viable option "if we wished to continue to preserve our strategic deterrent expertise."[297]

Why was a Skills-based Argument Successful in 1968 but not 1962?

The skills-based arguments forwarded in 1962 and 1968 were both unsuccessful in immediately obtaining further work. Nonetheless, given the similarity of the arguments used by AWRE in 1962 and 1968, it raises the question of why did tacit knowledge-based arguments forestall reductions only in 1968, but not 1962? Many of the same mechanisms for limited oversight of the nuclear weapons establishment had been present throughout the 1960s. For instance, Maguire notes that in 1963, "Zuckerman did not attempt to conceal his belief that the scientists at Aldermaston were under too little control, arguing that lack of 'executive authority' meant that the direction of 'long term research... is left almost completely to [AWRE]'."[298] While Zuckerman was clearly a partisan observer, AWRE would go on to explicitly assert their autonomy from potential sources of governmental oversight such as MinTech in the intervening period.[299]

Perhaps the simplest explanation for this discrepancy was that the AWRE of 1962 was overstaffed to such a degree that the expenditure it incurred made it impossible for it to be

[293] TNA, PREM13/2493, Note for the Record – marked 33, (n.d.)
[294] Jones, (2)(2017), p.490-494
[295] Stoddart, (2012), p.140
[296] Freedman, (1980), p.51-53, Stoddart, (1) (2014), p.48-49
[297] TNA, DEFE25/509, Options for Improving the Polaris Force, (n.d.)
[298] Maguire, (2007), p.127
[299] Jones, (2)(2017), p.278-81

continued at its then rate; 8715 staff were employed by AWRE, compared to 6370 by 1967.[300] The elevated level of staffing was sustained on the basis of the Sandys' conception of nuclear based deterrence and the short term requirement of expanding and anglicising the nuclear arsenal. Arguing that the 1962 figure represented a minimum staffing complement was not attempted (and untenable given 7590 were employed in March 1958, at the height of the Grapple tests); the argument justified the retention of a core cadre of around half of the then staff that would be then necessary for maintenance. [301] From this perspective, the need for a minimum complement of around 4500-4800 required for post-design challenges was remarkably consistent throughout the 60s; the 6000 figure included staff employed on diversified work.[302] With the figures in 1968 approaching what AWRE had therefore maintained was approaching a minimum, the weapons establishment was credibly able to raise "threat uncertainty" over the risk posed by nuclear weapons 'uninvention' through skill loss.[303]

Although reducing expenditure on nuclear weapons was important to the governments in power in 1962 and 1968, the second clear factor was the differing political commitment to changing the role of nuclear weapons within British defence policy. The move away from Sandys' conception of nuclear deterrence to a more flexible defence policy, while imposing economies necessitated reductions under the Macmillan government. Therefore, an affirmative political decision had been made to reduce nuclear weapons research and development spending. Both Watkinson and Thorneycroft were raised to their roles as SofS to oversee reductions, so were unlikely to be swayed. In contrast, Labour was split several ways over unilateral disarmament (for moral or financial reasons), internationalisation or maintenance of the status quo.[304] A lack of political consensus lowered the function of the NRDC which had provided a 'civilian' check to nuclear ambitions during Macmillan's tenure, which in the Wilson administration "met too infrequently to perform the function of continuous oversight that was required."[305] With Healey supporting arguments

[300] TNA, CAB134/3120, British Nuclear Weapon Policy – Report by the Defence Review Working Party – Appendix 1 to Annex 5, (n.d.)
[301] TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962 & TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962, TNA, AB16/3240, Weapons Programme: Defence Committee Papers, 28/06/1962 & TNA, CAB134/2239, Effect on Atomic Energy Authority of the Proposed Revised Nuclear Warhead Programme, 30/05/1962. How the UKAEA produced this "estimate" is unclear. Moore gives the envisaged figure as 4800 by 1967/68. Moore, (2010), p.199
[302] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment – Minority Report, 07/1968 & TNA, CAB148/55, OPDO Meeting Minutes, 08/09/1967
[303] Saunders, (2019), p.184
[304] Healey, (2015), p.241
[305] Jones, (2)(2017), p.331

forwarded by MoD officials and Wilson being notably pragmatic, it was easier to defer decisions, rather than force the issue.

Within Saunders' framework on the domestic politics of nuclear weapons decisions, the differences between Macmillan's and Wilson's commitment to their nuclear weapons policies could be characterised as 'mobilisation' versus 'delegation.'[306] To obtain consensus on defence reductions, Macmillan expanded the circle of actors involved in discussing nuclear issues under the Future Policy study. The NRDC provided further civilian oversight over AWRE, which allowed the principal to enforce their will after firmly establishing their intentions. Wilson handled the combined threats of improving Soviet ABM systems and the potential for nuclear uninvention. In contrast, Wilson was unwilling to divide his polarised cabinet over nuclear weapons issues so delegated them to the defence bureaucracy. The Kings Norton Inquiry was a further symptom of delegation and it lacked mechanisms to interrogate information provided by AWRE. Wilson's strategy of delegation exacerbated principal-agent issues over information asymmetry as the core issue was that of incommunicable skill.[307] Only the weapons establishment was in an authoritative position to provide answers.

It is also hard to deny the role of personal dynamics in influencing nuclear policy in the 1960s: Healey and Zuckerman did not get along, speeding Zuckerman's move to the Cabinet Office and away from a position of greater oversight over AWRE.[308] The combination of Macklen and Cook within the MoD, with Penney, Newley and later Peter Jones at AWRE dictated the terms on which information was provided. This influence over defence policy had perhaps been amplified by the centralisation of the MoD in 1964.[309] Frank Cooper (in 1968 Deputy Under-Secretary (Policy), MoD) stated to the Public Accounts Committee in 1980 that the role of Macklen in particular was "an inheritance of the early days of nuclear work. It was kept for a very long period of time within an exceptionally limited circle of people who were privy to the innermost details of nuclear thinking and nuclear technology."[310] Clearly, those outside of this circle faced immense difficulties gaining access to nuclear weapons information, further exacerbating the information asymmetries inherent in the nuclear weapons principal-agent relationship.[311]

[306] Saunders, (2019), p.175
[307] Kampani, (2014), p.72
[308] Healey, (2015), p.260
[309] Jones, (2)(2017), p.14-15
[310] Committee of Public Accounts, Ninth Report, Session 1981–1982, Ministry of Defence: Improvement to the Polaris Missile System, 17/03/1982, p.13
[311] Kampani, (2014), p.72

Conclusion

Based on previous experience with retaining staff, Nyman Levin suggested in 1960 that AWRE needed high levels of skills to solve post design challenges. Aldermaston's representatives continued to develop these arguments in the face of unprecedented reductions to nuclear weapons research and development by 1962. The skills' 'special' nature, fragility and the irreversibility of their loss was suggested to the government. Although the use of this argument is noted in some of the secondary literature, the process of Aldermaston's management increasingly acting as heterogenous engineers is underappreciated. [312] However in the early 1960s, due to firm political commitment to a reduction on high levels of spending on nuclear weapons and limited AWRE influence on the cabinet, attempts to obtain an ongoing research programme were unsuccessful. Nevertheless, the Skybolt Crisis and the Nassau Agreement provided several new projects, which temporarily alleviated the situation for Aldermaston.

Despite the efforts to further diversify work at Aldermaston, this chapter has demonstrated that AWRE was concerned about a 'brain drain' throughout the 1960s. This was a common concern for British industry and research establishments, but particularly worrying for Aldermaston because of the difficulties in acquiring enough ancillary research to retain 'high quality' staff. The overall perception of 'brain drain' led to Prime Minister Wilson's call to unleash the 'white heat of technology,' suggesting that he may have been uniquely susceptible to concerns over loss of knowledge and skills from the weapons establishment. This process ensured that the pause in arguing for new projects between 1962 and 1966 was only temporary.

When the renewed need for further projects reoccurred, William Cook was well placed in his role at the MoD to advocate for new weapons projects to the new Labour government in 1966. As this chapter has evidenced from primary sources, Cook initially suggested Polaris hardening as a method to retain skills within the establishment. This proved to be highly controversial within the Wilson government, with some ministers in favour of unilateral disarmament. With finding a consensus proving elusive, the Wilson government delegated finding a resolution to the Kings Norton Inquiry. Although intended to determine the minimum level of staffing at AWRE, the panel reiterated information provided by AWRE and therefore only recommended superficial reductions.

[312] Stoddart, (2014), p.159

While the inquiry was censured for failing to critically examine the limited information it was provided, it was unclear how it could have succeeded. The conception of tacit knowledge presented by AWRE meant that assertions of their expertise stemmed from their identity as 'weaponeers.' Given the technical and secret nature of nuclear weapons work, the panel were not able to credibly challenge the needs of AWRE, despite Rothschild's efforts. Nonetheless, the Kings Norton Inquiry was perhaps the best opportunity under Wilson's first government for nuclear weapons and economic sceptics to denude the establishment of resources. It had failed to do so, and the subsequent years of the Wilson administration were occupied with considering wider reform to government research establishments and the UKAEA; a decision on Polaris hardening was deferred beyond the next election. No affirmative decision was made by the Wilson government either way regarding Polaris hardening, but due to the autonomy of AWRE within the UKAEA, continually greater resources were directed towards the project. Polaris hardening was not provided as 'make-weight' work for Aldermaston, but the value placed upon AWRE's skills in the Kings Norton Inquiry proved a defence against staff reductions, which in turn proved a strong justification for further weapons research.

The failure of the Kings Norton Inquiry to determine a minimum staffing level for AWRE reflected the established inability of the Ministry of Technology and the UKAEA to scrutinise the British nuclear weapons establishment. This has already been noted in the secondary literature, but while this chapter concurs, it also suggests that this was a systemic problem due to the secrecy surrounding Aldermaston. As only those with a close connection to the weapons establishment were qualified (and permitted to develop such expertise) to comment on the tacit knowledge requirements of the work, individuals with a favourable view of AWRE's institutional interests were best placed to argue from a position of authority. Therefore a select few individuals, such as William Cook and Victor Macklen, had a uniquely important role in influencing policy.

In conclusion, throughout the 1960s, AWRE developed an independently conceived notion of the 'uninvention hypothesis,' which was used to justify ongoing weapons developments. This belief established a reoccurring process where in periods when AWRE was near the end of its assigned project work (1954, 1958, 1960-1962, 1966-1968), arguments over the need to retain skills came to the fore. This reflects the cyclical nature of morale at the establishment and the search for a sustainable workload. Although the argument was not successful in preventing cuts in 1962, it was in 1968. This was important given the political climate; Hennessy states that the outcome of the Kings Norton Inquiry was that "Aldermaston survived."[313] As demonstrated by this chapter, this was

[313] Hennessy, (2007), p.251

enabled by delegation of nuclear decision making away from the principal; Wilson continually deferred on nuclear weapons issues as his cabinet was split between unilateral disarmament and ongoing modernisation. This allowed AWRE to maintain the status quo, whilst the scientific momentum cited in primary documents was converted into Beyer et al.'s "bureaucratic momentum" as more spending was accrued on Polaris hardening.[314] The tacit knowledge of the scientists and engineers at Aldermaston was 'sold' to the Wilson government, rather than Polaris hardening.[315] These early efforts are therefore distinct from either a 'technology out of control' or a 'politics in command' model of technological development.[316] While it could be deemed that this effort was simply an exercise in retaining resources at the establishment out of simple institutional interest, the next chapter will assess further measures taken in the aftermath of the Kings Norton Inquiry to retain skills in an effort to avoid 'uninvention.'

[314] McLean and Beyer, (1987), p.149
[315] Spinardi, (1998), p.251
[316] Spinardi, (1997), p.548

Chapter 6: AWRE in Transition – Kings Norton to TASM (1970-1993)

Introduction

This chapter traces the development of AWRE from after the Kings Norton Inquiry in 1968 to contractorisation in the 1990s. The first mechanism examined is how both Labour and Conservative governments attempted to exert greater oversight on Aldermaston by reorganising the weapons establishment away from the UKAEA and into the MoD. This centralisation diminished AWRE's ability to advocate for its institutional interests, contributing to an austere period for Aldermaston, wherein staffing levels reduced. This chapter demonstrates that centralisation of AWRE under the MoD led to staffing reductions, which in turn contributed to several plutonium contamination cases in 1978, which necessitated remedial work. Although extending beyond hypotheses drawn from the secondary literature, it is argued that the incoming Thatcher government had its nuclear ambitions limited by AWRE's capacity; Aldermaston's inability to recruit and retain staff periodically even threatened the Trident programme. This prompted moves towards introducing private management of Aldermaston in 1989, which (like the foundation of the UKAEA in 1954) was an attempt to provide the organisation autonomy, free from civil service restrictions. Throughout this period, AWRE attempted to improve knowledge management practices internally. This manifested with the introduction of trickle production, simulation facilities and a bid to produce a new generation of tactical nuclear weapons. The chapter will conclude with Aldermaston making a final failed use of the tacit knowledge based 'uninvention' argument in 1993. After CTBT negotiations halted live nuclear tests, Britain's nuclear weapons project undertook a rapid transition away from associating the credibility of the deterrent with the experience of scientists and technicians, and instead towards seeking alternative technical means.

Limitations

In seeking to trace Aldermaston's more recent history, the limitations on the available sources become ever greater. As with previous chapters, many of the archival documents on the subject remain classified or unavailable due to an ongoing security review at time of writing. Due to the period involved being closer to the present, few files have been released to the National Archives for public access beyond the 1970s. Although many would be available under the 30 or new

20-year rule, many files are still restricted on national security grounds.[1] However, this is somewhat offset by the greater availability of public information provided by parliament's Defence Select Committee, which was established in 1979. Even so, there are no official histories of this period available at time of writing and many of the secondary sources are limited to citing interviews and confidential correspondence. Stoddart's series on British nuclear weapons history grapples with these challenges, but he only covers the programme until 1983.

Despite these limitations, this chapter attempts to trace the impact of the Kings Norton Inquiry and how the pressure to preserve tacit knowledge within AWRE continued to be a perennial concern. It does not seek to generate a definitive history of this period, both due to necessary brevity and the availability of sources; wider political and strategic debates are cited only when relevant. Instead, this chapter will focus on how concerns over knowledge management were handled within Aldermaston, influenced its organisation, were communicated with the MoD and government and how these in turn effected nuclear policy.

Impact of the Kings Norton Inquiry

Institutional Development: Implementing Oversight

While AWRE was able to forestall immediate staff reductions after the Kings Norton Inquiry, this proved to be a pyrrhic victory. The ability to resist oversight demonstrated in the previous chapter ensured that a counteracting process was near inevitable. Measures were contemplated that would ensure greater principal control over the establishment. Even the usually sympathetic MinTech and MoD had reached a consensus in 1969 that while the Kings Norton Inquiry had believed that "nuclear weapons work 'is fundamentally different from other kinds of defence work'…We believe this view to be mistaken."[2] Despite the inquiry, AWRE was still deemed inefficient as it was spending more than three times as much on supporting research and development (such as material science, health physics and experimental physics) than it was on warhead work for the MoD.[3] The perpetuation of this situation was deemed the result of "[the] management of A.W.R.E., [which] the Authority has in practice a large measure of autonomy with little challenge from

[1] The National Archives, (2019)
[2] TNA, AVIA65/2198, Future of AWRE, 26/11/1969
[3] Ibid.,

Government Departments about the validity of its technical judgement or the detailed efficiency of its management."[4] The consequence of this was that "A.W.R.E. cannot be subjected to detailed oversight."[5] It was suggested that research autonomy had benefits in the 1950s, but now the maturity of nuclear weapons technology meant that more control over research was now deemed necessary.[6]

Due to the repeated inability to impose economies on AWRE since 1966, there was strong support within Government and the civil service to reorganise the establishment so that it would be more firmly under government control.[7] David Owen, then a Defence Minister believed that "Although responsibility for… [AWRE] was nominally shared between the Ministry of Technology and the MoD, this had little practical effect."[8] To correct this, the Wilson and then Heath government's objective was "to bring AWRE within the MOD organisation."[9] Given the multiple stages of removal between meaningful technical or contractual oversight, it was believed that "benefits would flow from an early and firm decision on future responsibility for the control of the establishment."[10]

Although the merits of a reorganisation of AWRE were recognised, their implementation was delayed by wider considerations of how best to reorganise other government research establishments and how to structure the remaining UKAEA civil programme. Wilson favoured creating a singular large British Research and Development Corporation, but AWRE was perceived to be unsuitable as part of this commercially minded venture.[11] As Polaris Improvement and further economies were "closely tied" with AWRE's restructuring, a definitive decision on whether to progress was also delayed.[12] A working party had been formed to study the future of AWRE.[13] While legislation was pending for the reorganisation of the UKAEA, these plans were disrupted by the 1970 general election.[14]

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[4] Ibid.,
[5] Ibid.,
[6] TNA, AVIA65/2198, Future of AWRE, 26/11/1969 & TNA, PREM15/300, Future of AWRE - Armstrong to Prime Minister, 16/07/1971
[7] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.)
[8] Owen, (1972), p.203
[9] TNA, DEFE13/925, The Future of AWRE, 08/10/1969. The Ministry of Technology also campaigned for AWRE to be placed directly under their administration. TNA, CAB168/8, Future of AWRE, (n.d.)
[10] TNA, CAB134/3120, Ministerial Committee on Nuclear Policy Minutes, 09/07/1969
[11] TNA, DEFE13/925, Green Paper on Industrial R&D, 16/12/1969
[12] TNA, DEFE13/925, Future of the Atomic Weapons Establishments, 09/07/1969, TNA, DEFE13/548, Note of a Discussion Between the Secretary of State for Defence, CA(PR), ACSA(SN), DUS(P) and AUS(POL), 12/02/1969 & TNA, CAB168/8, Future of the Atomic Weapons Establishments - Zuckerman to Prime Minister, 09/07/1969
[13] TNA, CAB168/9, AWRE Enquiry, 29/07/1969
[14] Patterson, (1985), p.20 & TNA, DEFE13/925, Nuclear Fuel Company and the Future of the AEA, 03/10/1969

The Heath administration adopted and proceeded with the research rationalisation agenda.[15] Heath tasked Derek Rayner with generating proposals to reorganise UK defence procurement. Rayner was a prominent businessman and was brought in to introduce modern financial management practices into the sector.[16] His report, which was quickly accepted by the government, was delivered in April 1971 and recommended that the MoD establish a single Procurement Executive. All the previously disparate research establishments would report to this new organisation.[17] The transfer of AWRE to the MoD was viewed as "an essential pre-requisite to an economical rationalisation" of defence research and was "urgently necessary."[18] Neither in the Rayner report or policy documents was the objective of asserting more control over AWRE expressly stated. The word "control" had been deliberately removed from an initial draft, but the intention was still to "ensure that objectives are set by customers [i.e. the MoD]."[19]

The proposal faced resistance. AWRE management believed that their transfer to the MoD would threaten its future supply of civil work.[20] Given that reducing extraneous spending was the intention, the fear was grounded, but likely to be rejected. The UKAEA also raised the objection that it would disrupt the cooperation between Harwell and Aldermaston on civilian reactor work (particularly on the fast reactor programme) at a "critical time."[21] Their other argument was that it would further erode the confidence of their staff as the organisation progressively shrunk with the splitting off of the British Nuclear Fuels Ltd and Radiochemical Centre Ltd in 1971.[22] However, the UKAEA had also resisted these efforts in 1969 on the same grounds, stating that "disintegration of the nuclear effort would be most disadvantageous technically at the present juncture."[23] The repeated allusion to technical matters to defer bureaucratic reform was ironically what hiving AWRE from the UKAEA was intended to overcome. While the plan had been to settle the "absorption" of AWRE into the MoD by 1st April 1972 "in order to prevent the discussion dragging on indefinitely," the practical difficulties of the "legislative timetable" ensured further delays.[24] Changes to the law were necessary in order to transfer the existing AWRE workforce back into the civil service.[25] The bill

[15] TNA, CAB168/9, The Future of AWRE, 29/01/1971
[16] Theakston, (1999), p.229
[17] HM Government, Command Paper 4641, Government Organisation for Defence Procurement and Civil Aerospace, 04/1971, p.3
[18] Ibid., p.39
[19] TNA, CAB168/10, Defence Procurement and Civil Aerospace - Rayner Report, 26/03/1971
[20] TNA, CAB168/10, Future of AWRE, 12/07/1971
[21] TNA, CAB168/10, Future of AWRE - 2, (n.d.) & TNA, PREM15/300, Summary of the Report of the Interdepartmental Working Party, 14/07/1971
[22] TNA, CAB168/10, Future of AWRE - 2, (n.d.) & TNA, PREM15/300, Brief for the Prime Minister - Transfer of AWRE to the Ministry of Defence, (n.d.)
[23] TNA, DEFE13/925, Nuclear Fuel Company and the Future of the AEA, 03/10/1969
[24] TNA, CAB168/10, Future of AWRE, 12/07/1971 & Dalyell, (1973)
[25] Dalyell, (1973)

proved relatively uncontroversial (being framed as a mundane administrative matter), with the process complete by mid-1973, AWRE was hence part of Procurement Executive under the Controllerate of Research and Development Establishments and Research.[26]

In a retrospective assessment, a 1980 Treasury review of the organisation of Britain's nuclear weapons programme made clear that "the need to ensure closer MOD control over and regulation of the executive management of the nuclear weapons programme was a major consideration leading to the setting up of the present organisation in 1973 – There is no doubt that this has been achieved and was a major advantage of the 1973 reorganisation."[27] It had been apparent to both the Wilson and Heath administrations that AWRE was too freely able to control the flow of information to influence policy decisions towards the establishment's desired outcome. While the transfer to the MoD would rectify this problem, it helped contribute to a crisis at Aldermaston in 1978 to 1979 that threatened the continuation of Britain's weapons programme.

Reducing Personal Influence

Given that asserting more government control over the weapons establishment was one of the objectives of transferring AWRE to the MoD, the impact that this had on the influence of key officials must be examined. A legacy from the foundation of the British nuclear weapons effort was that scientists and civil servants involved in nuclear issues had a close relationship with senior government members, although this had somewhat waned with the departure of figures such as Cook and Penney.[28]

Nonetheless, the consolidation of the MoD in the 1960s had given the Chief Scientific Advisor (CSA) and/or Chief Advisor (Projects) (CA(P)) in the MoD significant influence over nuclear policy, without a responsibility for auditing AWRE's performance.[29] The personal influence wielded by William Cook as Chief Advisor (Projects) and Macklen amongst others, combined with the weakness of the Ministry of Technology and UKAEA in auditing the establishment was seen by Zuckerman to have allowed for parochial interests to dictate nuclear policy and spending to increase

[26] TNA, CAB168/143, Zuckerman to Cooper, 09/12/1970 & TNA, CAB168/10, Future of AWRE, 12/07/1971
[27] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.)
[28] As seen below, William Cook's advocacy in favour of laser simulations facilities for Aldermaston was sought by Macklen to the SofS, rather than contemporises then employed at AWRE.
[29] Miall, (1987), p.58

unchecked.[30] Zuckerman complained that the nuclear weapon establishment had acted as a "'free' agent" and strongly advocated that when AWRE was transferred to the MoD, further reforms should be made as "a simple transfer… would just not do."[31] Zuckerman's proposal to the Prime Minister, which was implemented, was that the MoD CSA must have a "direct link" to the establishment to influence the "directions and purpose" of nuclear weapons developments but "the execution of already agreed policy" would be controlled by the new Procurement Executive.[32]

The ability of Aldermaston to conduct discretionary research was to be severely curtailed as all projects would be approved of by the CA(P) who would "finally decide the programme of work he wishes to have executed." [33] The director of Aldermaston would be firmly subordinated to the CA(P), who in turn would answer to the MoD CSA and SofS. The Procurement Executive would "make informed judgements on resource allocation problems," making sure that AWRE would conform to the agreed agenda.[34]

While this separation of responsibilities was the theoretical settlement from 1973 onwards, it was swiftly undermined by the delegation of the financial oversight responsibilities of the Procurement Executive for the Chevaline programme back to CA(P).[35] Given the objective of the reforms to the management of AWRE, this seems odd. In an attempt to explain why this occurred, Frank Cooper stated in 1980 that it was "normal" for nuclear work to be overseen by a small number of individuals as it "was an inheritance of the early days."[36] While it was alleged that this contributed to the increase to the cost of Chevaline during this period, select officials influencing weapons policy remained an ongoing issue.[37] For example, even after Macklen's retirement in 1979, his influence continued as he gave advice on nuclear matters to subsequent MoD CSAs.[38]

Although influence over nuclear policy remained invested in select MoD officials, AWRE's sway on policy through its directors did diminish because of the 1973 reforms. While Cook and Penney had enjoyed direct access to the Prime Minister during their tenure at AWRE, the 1973

[30] Zuckerman, (1989), p.389-390. Chief Advisor (projects) was William Cook's new position after Zuckerman was moved to the Cabinet Office in 1966. Theoretically equal to Chief Adviser (Studies) within the MoD, Cook was more "primus inter pares" and more akin to the CSA. Broadbent, (1988), p.154
[31] TNA, PREM15/300, Future of AWRE - Zuckerman to Prime Minister, 29/03/1971
[32] TNA, PREM15/300, Future of AWRE - Zuckerman to Prime Minister, 29/03/1971 & Broadbent, (1988), p.155-156
[33] TNA, DEFE7/2371, Application of Rayner Arrangements to AWRE, 20/07/1972
[34] Ibid.,
[35] Miall, (1987), p.58 & Committee of Public Accounts, Ninth Report, Session 1981–1982, Ministry of Defence: Improvement to the Polaris Missile System, 17/03/1982, p.2
[36] Miall, (1987), p.59 & Committee of Public Accounts, Ninth Report, Session 1981–1982, Ministry of Defence: Improvement to the Polaris Missile System, 17/03/1982, p.13
[37] Stoddart, (1) (2014), p.167
[38] The Times, (1993)

reforms subordinated the director of Aldermaston within and under the MoD. This was clearly demonstrated in 1978 with the appointment of David Cardwell as the establishment's director.[39] Spinardi highlights how Cardwell (and his successor Colin Fielding) was a "career civil servant brought in from outside."[40] Cardwell's AWRE biography in 1980 makes no mention of nuclear experience before 1978.[41] Cardwell still advocated for AWRE, but unlike Penney or Cook, it does not appear that he was consulted or cited by ministers of senior civil servants to the same degree as his predecessors.[42]

Effect of 1973: AWRE in Decline?

One of the main objectives of the defence rationalisation agenda was to improve the efficiency of British defence research efforts by removing duplicate capabilities across multiple institutions. [43] The closure or downsizing of other defence research establishments was meant to provide compensatory work to AWRE to offset the loss of its civil diversified research programme. Civil work had consistently been viewed as cost inefficient and was set to be curtailed as AWRE was moved out of the UKAEA.[44] With defence work intended to make up for civil shortfalls, it was important for it to be transferred promptly.[45] While some work was transferred, the process had "not been implemented to any significant extent" by 1980.[46]

The problem this posed can be shown through the proportional increase of man years devoted within AWRE to the Defence Nuclear Programme (DNP) compared to civil diversified research and non-nuclear defence research, despite the DNP's absolute decline with the completion of Chevaline research and development.[47] In 1970, the DNP was 70% of the effort, 22% to civilian diversification and 8% to non-nuclear defence work. By October 1979, "about 18% of AWRE's… [effort was] deployed on defence non-nuclear work" while "some 4%" was still on civilian

[39] Spinardi, (1997), p.568
[40] Ibid., p.568
[41] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department - Biographies, 09/1979
[42] His name only appears infrequently in documents to the SofS, such as TNA, DEFE19/157, AWRE Aldermaston, 13/09/1978
[43] TNA, DEFE13/925, Future of the Atomic Weapons Establishments, 09/07/1969
[44] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[45] TNA, DEFE13/1768, Nuclear Weapon Research, 09/09/1976, although this could be circumvented for a while for "as development work on Chevaline runs down the amount of basic research done will increase"
[46] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.)
[47] While comparing budget sizes may seem the obvious mode of comparison, rampant inflation in the 1970s and different funding models between the MoD and UKAEA lessen its utility.

diversification work, with the DNP presumably accounting for at least 78% of the effort.[48] This declining proportion of work other than the DNP was worrisome as 1979 represented a relative lull in the development activities at Aldermaston; while Chevaline was in production, no major development project was underway.[49] This indicates that the total amount of work available to the establishment had significantly declined. While the rationalisation agenda continued to be slowly implemented (such as with the transfer of high explosive research to AWRE from 1979), civil research at AWRE continued to decline, with it reaching 3% of AWRE's workload in 1980.[50] Although the reduction of work allowed for economies at AWRE, the perception of the establishment in decline further convinced staff to seek employment elsewhere, which in turn contributed to the next process of fears over safety at Aldermaston in the late 1970s.

Reusing Uninvention: Simulations and Initial 'Black Boxing'

Even with Aldermaston's subordination to the MoD, AWRE continued to use the 'uninvention' argument to acquire further projects. A reiteration of the arguments used to justify the Polaris Improvement Programme were deployed in favour of acquiring experimental laser plasma fusion facilities at AWRE in 1976. As with Polaris Improvement in 1966, the re-emergence of these arguments came with the imminent completion of a campaign of work. In this case, AWRE's role in the "theoretical" development of Chevaline was "due to be completed" with the Anvil nuclear tests in 1976.[51] This would mean AWRE would lack a main research and development project. This could also mean a renewed suspension of nuclear testing. According to Macklen, when this had occurred between 1965 and 1974, it had resulted in "the effectiveness of AWRE… [deteriorating] considerably."[52]

Unsurprisingly, the question of what work would sustain the establishment's future returned to the forefront of Macklen's agenda. While the preferred candidate was a new strategic nuclear system, the Labour government refused to discuss a successor system for Chevaline in 1976 "for at

[48] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979, in the report, the DNP is estimated at around 83% of deployed resources. Either these figures are incorrect, or there was some overlap between defence nuclear and non-nuclear research.
[49] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[50] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.) & TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[51] Stoddart, (1) (2014), p.161
[52] TNA, DEFE13/1768, Nuclear Warhead Research and the Capabilities of AWRE, 06/09/1976

least two years."[53] It is within these circumstances that AWRE launched a bid to acquire new laser facilities for itself in 1976, that would allow for the simulation of fusion reactions in warheads.[54]

Early efforts to use lasers for fusion simulations had begun in 1971, and these experiments offered "the prospect of investigating some facets of nuclear weapons design without nuclear tests," if larger, more powerful facilities could be deployed.[55] Nonetheless, tentative approaches to secure further funding were rebuffed by a "distinctly sceptical" SofS in May 1976.[56] A further barrier to AWRE was fierce competition from Harwell over where to base fusion research given intense budgetary pressures.[57] To secure AWRE's case, a report was delivered by both Victor Macklen and William Cook to the MoD CSA.[58] Macklen opened that "the current programme of nuclear research work on Chevaline is nearing completion… [and] the time has now come to formulate the policy for the future research programme on which the highly skilled teams at AWRE should be re-deployed."[59] He further claimed that "the report is written on the assumption that Ministers will wish to retain a worthwhile nuclear capability."[60] To do this, "approval for a future warhead research programme is necessary."[61] With the Labour government's reluctance to approve a continuing test programme or firmly commit to a new nuclear system, new laser facilities were held to ease the need for progress with "weapon design without nuclear tests" and progress tentative research into advanced design concepts.[62] In order to support this argument that some programme was necessary, Macklen highlighted how AWRE was operating below the minimum manpower and financial requirements that had been specified in 1966.[63] In a further similarity to prior iterations of the same argument, consultation offered by William Cook offered "that a positive UK programme would open the doors in the USA to information."[64]

Although the above report made clear appeals to the possibility of nuclear uninvention, these warnings would only get stronger in September 1976. The MoD CSA, Hermann Bondi suggested to the SofS that "the nuclear field does not differ from any other field of defence

[53] TNA, DEFE13/1769, Review of the Chevaline Project, 20/07/1977
[54] Stoddart, (1) (2014), p.161
[55] TNA, DEFE13/1768, Nuclear Warhead Research and the Capabilities of AWRE, 06/09/1976. This was not a new idea: hydrodynamic experimentation had been conducted at Aldermaston since the 1950s, but this was expanding simulation into new areas. Hawkings, (2000), p.97
[56] Stoddart, (1) (2014), p.182
[57] New Scientist, (1975)
[58] TNA, DEFE13/1768, Nuclear Warhead Research, 06/09/1976
[59] TNA, DEFE13/1768, Nuclear Warhead Research and the Capabilities of AWRE, 06/09/1976
[60] Ibid.,
[61] Ibid.,
[62] Ibid.,
[63] Ibid.,
[64] Ibid.,

capability in so far as the possibility of future development depends on the existence of an active research programme."[65] Macklen additionally forwarded to the SofS that the "basic question" for Ministers to consider is "whether to stay in the nuclear weapons business against a hypothetical future requirement plus an actual requirement to refurbish certain warheads in the 1980s, or whether to let our capability run down."[66] The invocation of the uninvention argument appears to have succeeded as in October 1976, the establishment acquired permission to proceed with capital spending for laser fusion facilities.[67] This approval was maintained even in the face of further price increases to the project in February 1977.[68] Nonetheless, by 1979, the new HELEN laser facilities were in operation.[69]

This incident clearly demonstrates the continuing use and potency of the 'uninvention' argument to justify further research commitments at AWRE to retain skills embodied within people, who needed a constant supply of work to keep them in post. On the other hand, the acquisition of fusion simulation facilities at Aldermaston was an early indication of the establishment in transition. Instead of placing the emphasis of retaining the credibility of nuclear weapons through tacit knowledge, the laser facilities were a clear move towards a more technically based process, guaranteed by scientific data rather than design experience.[70]

In 1978, Macklen praised this approach in a presentation to American colleagues, believing that it would allow for new meaningful data to be exchanged with the US (thus satisfying the MDA), allow for a CTBT to be implemented while retaining nuclear weapons capability and increase the economic efficiency of the nuclear weapons programme by reducing the demands for live nuclear weapons testing.[71] The importance of adopting this approach was highlighted by the resumption of negotiations towards a CTBT in 1977; simulations and a few last tests were necessary to obtain a "stock of proven technical knowledge….[to ensure] really fruitful and deep US/UK collaboration on stockpile maintenance problems in the event of a CTBT."[72] This approach was promptly continued with the commissioning of the MOGUL X-ray radiography facilities. The use of simulation and experimentation facilities to generate weapons maintenance relevant data became known to the Americans as "The English Concept."[73] As pressure to invest in the HELEN facility had been in explicit

[65] TNA, DEFE13/1768, Nuclear Warhead Research, 06/09/1976
[66] Ibid.,
[67] TNA, DEFE13/1768, Laser Fusion Facility at AWRE, 31/01/1977
[68] Ibid.,
[69] Miller, (2009)
[70] Ibid.,
[71] TNA, DEFE19/240, UK Stockpile Reliability in the Absence of Nuclear Experiments, 01/02/1978
[72] TNA, PREM16/1977, British Nuclear Test Programme, 27/04/1978
[73] Hawkings, (2000), p.100

response to the possibility of a renewed suspension of British nuclear testing, it is unsurprising that similar arguments increased in frequency in 1990s with renewed negotiations towards a CTBT.[74] There were the amongst first tentative moves of repositioning nuclear weapons credibility away from being embodied within people towards a 'black boxed' technical process.[75]

Pochin and AWRE: Uninvention Manifest?

Situation before 1978

Despite raising the potential for uninvention, AWRE had its staffing levels reduced progressively from 1968 to 1978. This was not a new trend; during the 1960s and early 1970s, staff reductions had disproportionately fallen on skilled labour rather than scientists.[76] A halt to the gradual reduction of staffing levels at AWRE was meant to be implemented in 1975 but did not occur due to the transition to the MoD in 1973.[77] Thereafter, general reductions in overall defence spending meant that further reductions were made at AWRE; once again disproportionately fell on skilled labour rather than scientific grades.[78] Subject to further defence budget cuts, government policy was for reduced staffing levels across all MoD defence establishments in 1974.[79] As a result, the agreed complement for skilled labour at AWRE was reduced in 1975 and again in 1976.[80] The net result was that while the total strength for scientific grades at AWRE was at 75% compared to its 1961 level, skilled labour was at 50%.[81]

Why AWRE retained scientists over other skilled technicians is unclear. Although often vague in terms of referencing broad 'skills,' arguments since 1962 favoured of preserving research rather than technical capacity. For example, fears over a 'brain drain,' the justification for diversification and the terms of the Kings Norton Inquiry were all made in reference to "retaining good scientific staff."[82] This bias may have been dictated by AWRE's composition: in 1961, scientific staff

[74] TNA, DEFE19/240, Record of a Meeting with Dr Frank Press, 16/02/1978
[75] MacKenzie and Spinardi, (1995), p.78-79
[76] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[77] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[78] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[79] Defence Committee, Fourth Report, Session 1980–1981, Strategic Nuclear Weapons Policy, Report and Minutes of Evidence, 20/04/1981, p.179: Reductions at staff at Aldermaston were in line with reductions across the rest of the MoD
[80] TNA, DEFE19/163, AWRE Aldermaston Complement and Strength Return Skilled Industrials, 10/08/1978
[81] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[82] TNA, CAB134/3121, Report by the Working Party on Atomic Weapons Establishment, 07/1968

outnumbered craft strength by nearly 2:1.[83] This makeup likely reflected the UK's attitude to nuclear weapons prior to 1958 which was progressively changing from favouring a varied nuclear arsenal towards retaining a select few weapons systems, kept in service longer.[84] An acknowledgement of this previous bias and subsequent realignment is present in a 1978 civil service briefing on AWRE that states "although AWRE has a research programme of high technological content, a major task is engineering design, development and fissile material component fabrication requiring engineers and industrial craftsmen of high skill."[85]

Retaining the remaining highly skilled craftsmen proved challenging; from early 1977 onwards, skilled labourers were leaving at a faster rate than planned reductions.[86] Even when the agreed complement of skilled labour for AWRE was rapidly raised in October 1977, staff continued to leave, and this trend accelerated in 1978.[87] This meant that while AWRE was meant to employ 678 skilled labourers by 1979, it was more than 100 below strength, and already at a comparatively low level.[88] As the events of 1978 would prove, this was a dangerous situation.

The trend of skilled labour leaving appears to have been the result of declining relative pay at AWRE for industrial grades after the 1973 transition to the MoD. At the time of the transition from the UKAEA to the MoD, pay for skilled labourers was substantially lower in the civil service than in the Authority, to the extent that the transition threatened industrial action that could have derailed Aldermaston's design and production schedules.[89] While pay for labourers who moved to the civil service regime was maintained at prior authority rates, any new labourers were paid at the lower civil service rate.[90] It was noted that Industrial Civil Service pay had "fallen behind outside employers since 1975." [91] When measured in 1977, the comparable "general level of earnings" was 20% below equivalent private industrial positions.[92] Finding better paid work compared to their "uniquely onerous responsibilities" would likely prove trivial given the prevailing "high employment" in the surrounding area.[93] Pay at AWRE even declined relatively compared to the UKAEA; extra bonuses paid to Authority workers had persistently been raised throughout the 1970s. In contrast,

[83] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978. 2132:1126
[84] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[85] Ibid.,
[86] TNA, DEFE19/163, AWRE Aldermaston Complement and Strength Return Skilled Industrials, 10/08/1978
[87] Ibid.,
[88] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[89] TNA, DEFE13/926, AWRE - Assimilation of Industrial Employees to ICS Pay and Conditions, (n.d.) & TNA, DEFE13/926, AWRE, 20/02/1973
[90] TNA, DEFE13/926, Draft Letter to the Lord Privy Seal, (n.d.)
[91] TNA, DEFE19/163, Titled - 'The Paper', 14/06/1978
[92] Ibid.,
[93] TNA, DEFE19/163, Pay of Industrials at the AWRE, (n.d.)

the bonuses paid to AWRE labourers had been fixed since 1973 and never renegotiated since AWRE had been transferred to the MoD.[94] As a result, pay for skilled labourers at AWRE was significantly below either alternative UKAEA or local private sector work and it was unsurprising that workers were leaving at an increasing rate.[95]

Plutonium Contamination

In 1978, the safety situation at Aldermaston exacerbated the ongoing problem of skilled industrial staff retention to a new degree. In August 1978, three laundry workers at Aldermaston were measured to have levels of plutonium contamination higher than international standards agreed by the International Commission on Radiological Protection.[96] Understandably, "[this] discovery caused considerable anxiety among those working at the establishment."[97] This spurred an inquiry into "Health and Safety at the Atomic Weapons Research Establishment at Aldermaston" (known as the 'Pochin' report as it was led by Sir Edward Pochin), which examined the radiological safety of the organisation. Pochin's report, produced in two months, recommended a series of improvements to safety at AWRE. Amongst the most important of these was that "an increase in maintenance staff is urgently [sic] required."[98]

Pochin identified that one of the major contributing factors for the decline of safety standards at AWRE were the reduced staffing levels; it was noted that in 1960 there had been 59 health physics staff at Aldermaston, but in 1978 there were 43 and in 1975 it had been as low as 38.[99] This reflected wider reductions at AWRE where staffing levels had declined to 4000, their lowest since the early 1950s.[100] These low staffing levels meant that safety considerations were neglected in the face of operational priorities.[101] In addition, the persistently low staff complement curtailed any safety improvements: AWRE management noted that "certain modifications to safety precautions identified in 1971 have still not been implemented."[102] The arbitrary reductions after Kings Norton therefore appear to have contributed to these events.

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[94] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 25/05/1978
[95] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[96] TNA, DEFE24/1346, An Investigation into Radiological Health and Safety at the MoD AWRE, 30/10/1978 – This number raised to 12 after further investigation.
[97] Michael McNair-Wilson, HC Deb 21 December 1979 vol. 976 cc1102-4
[98] TNA, DEFE72/450, The DCP and Downey Procedures, (n.d.)
[99] TNA, DEFE24/1346, An Investigation into Radiological Health and Safety at the MoD AWRE, 30/10/1978
[100] Urban, (1988). 4191 at Aldermaston, 357 at Foulness - TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department - Biographies, 09/1979
[101] McGinty, (1978)
[102] TNA, DEFE19/163, Implications of Shortage of Industrials at AWRE Aldermaston, 10/08/1978

Effect on Chevaline

Poor safety standards highlighted by Pochin meant that AWRE temporarily closed some facilities. Warhead production, already strained due to staff shortages, would be further delayed; remedial upgrades to fissile material handling facilities were required before they could be reopened.[103] Even the immediate closure of facilities deemed hazardous would produce serious short term demands in terms of manpower required to mothball them until they could be improved.[104] Fixing issues was also problematic; AWRE management noted in 1979 that despite "the contamination…[being] minor," the extra work burden to improve safety standards by the 1980s would place a "disproportionately great" strain on capabilities.[105]

These factors posed a serious situation for AWRE – the establishment had to take time away from production to improve safety, which threatened to derail the progress of the Chevaline programme. Problems with producing Chevaline were explicitly linked by officials to "Aldermaston's staff shortages," which included being "135 industrial grades short, many of whom could make a direct contribution to Chevaline."[106] This was despite a conscious effort to protect the Chevaline programme from the effect of staff reductions during the 1970s.[107] Nonetheless, management documents noted that in 1978, "AWRE had move from generally meeting…[agreed progress] dates, to generally not."[108] In mid-1979, AWRE noted that due to the safety concerns of the fissile material handling facilities, "fissile component production for all warheads including Chevaline has been at a standstill since August 1978."[109] Without rectification, it was noted that safety standards at AWRE would continue to decline, but also "a drastic reduction in the Military Programme" would be necessary.[110]

The shortages and reallocation of staff towards vital production or safety improvement was also affecting other areas of AWRE's work. For instance, even the production of documentation for Chevaline was falling behind schedule, which would delay its introduction into use; AWRE's management noted that "the fact remains that Coulport [main naval base for the UK's deterrent]

[103] TNA, DEFE19/183, The Critical Situation in Craft Labour Skills at AWRE, 05/01/1979
[104] TNA, DEFE19/163, Implications of Shortage of Industrials at AWRE Aldermaston, 10/08/1978
[105] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department - Biographies, 09/1979
[106] TNA, DEFE19/163, Chevaline Project at Aldermaston, 04/08/1978
[107] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 25/05/1978
[108] TNA, DEFE19/163, Chevaline Project at Aldermaston, 04/08/1978
[109] TNA, DEFE19/155, Pay of Industrials at AWRE, (n.d.)
[110] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978

have [sic] to have this documentation before they can handle our 'products.'"[111] The problem extended to the tactical nuclear weapons programme; in a report to the heads of the civil service, AWRE concluded in September 1979 that they "cannot support even one project adequately."[112] The situation was serious enough for it to be monitored routinely by Callaghan in 1978 and Thatcher in 1979.[113]

Rather than gradually improving, the safety situation was creating a vicious cycle. Skilled manpower was being lost as workers left for other employment, so safety conditions were further deteriorating.[114] This process was readily identified by David Cardwell, then Director of AWRE, who stressed that "the emphasis on Health and Safety legislation, the pressure on Chevaline and the need to refurbish many of the critical radioactive facilities at Aldermaston have all come together… just at a time when we need more staff we are forced into an accelerating loss rate which we judge will continue unless something positive is done to improve the situation."[115] This was placing the remaining staff in situations "completely outside any conditions of service which they would normally have expected to encounter."[116] This in turn would encourage the remaining workforce to leave, further exacerbating the maintenance problem. Cardwell complained on 2nd August 1978 to the MoD "that the industrial situation at AWRE is very serious indeed and unless the wastage in skilled labour can be reversed or at the very least reduced, the Establishment will become progressively less able to fulfil its forward commitments on the [Chevaline] programme."[117]

AWRE's advocates once again framed the situation as an existential crisis through 'uninvention' by skill loss. As Macklen noted, this was not simply a situation of balancing recruitment with wastage as "the plain fact is that we cannot recruit to replace wastage."[118] This was because work on "nuclear warheads is unique in that it is entirely dependent on intermural resources for production as well as R and D…. I cannot call on Industry for help or put AWRE… nuclear work out to contract."[119] By highlighting the singular and irreplaceable nature of the skills being lost, Macklen was once again appealing to wider tacit skills and 'uninvention' based arguments.

[111] TNA, DEFE19/163, Chevaline Project at Aldermaston, 04/08/1978
[112] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[113] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 25/05/1978 & TNA, DEFE19/155, Pay of Industrials at AWRE - Biffen to SofS, 13/07/1979
[114] TNA, DEFE19/155, Pay of Industrials at AWRE Report, 06/07/1979 – on average, between 1978 and 1979 when recruitment was urgently required, 8 craftsmen were leaving per month.
[115] TNA, DEFE19/163, Letter - Cardwell to Broadbent, 14/06/1978
[116] Ibid.,
[117] Ibid.,
[118] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 29/06/1978
[119] Ibid.,

Negotiating Solutions

As with previous problems with morale and retention, one of the main considered solutions was to offer better salaries.[120] However, in this respect, AWRE was constrained since it had "transferred from [the] UKAEA to MOD in 1973… [and was therefore] subject to Civil Service pay policy."[121] This meant that it was subject to the same pay restraint of the rest of the civil service and could not offer extra allowances then being offered by BNFL and the UKAEA to workers at Windscale to retain their own staff.[122]

As with recruitment in the early 1950s, AWRE had to promote other employment benefits that could potentially offset below average salaries. In 1978-1979, these included the provision of housing, applying price controls to rent, an assisted travel scheme, emphasising the civil service pension and the recreational facilities available to AWRE staff.[123] In addition, a recruitment campaign was advertised through "local and national newspapers, local radio and job centres."[124] However, the result of this effort was judged to be "almost total failure… despite strenuous efforts to gain recruits."[125] The offer of housing, which in the 1950s had been the key factor in AWRE recruitment was now judged to be "disappointing," even when targeted in areas of high unemployment.[126] It appeared to management that only a substantial pay increase to the base salary of the staff would rectify the situation.[127]

The proposed reform to improve retention and recruitment at AWRE was for an additional £15 per craftsmen per week to be paid to those working in the plutonium handling areas of Aldermaston.[128] However, as with other periods when attempts were made to improve the pay of sections of the industrial and scientific civil service, resistance was met.[129] This came from officials who wanted to retain pay restraint, other establishments that would not benefit from targeted

[120] TNA, DEFE19/163, Titled - 'The Paper', 14/06/1978
[121] TNA, DEFE19/163, The Windscale Allowance, 14/07/1978
[122] Ibid.,
[123] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 29/06/1978 & TNA, DEFE19/155, Pay of Industrials at AWRE, (n.d.)
[124] TNA, DEFE19/155, Pay of Industrials at AWRE, (n.d.)
[125] Ibid.,
[126] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[127] Ibid.,
[128] TNA, DEFE19/155, Pay of Industrials at AWRE - Biffen to SofS, 13/07/1979
[129] The process of obtaining approval was also likely delayed by the 1979 election, which meant appeals had to be made to the new Conservative government.

bonuses, the UKAEA and other sections of staff at AWRE (such as non-industrials), who would not receive bonuses.[130] In terms of the arguments used by those against privileging AWRE, officials highlighted how "other establishments have comparable recruitment and wastage difficulties…[and it was therefore part of a] wider problem."[131] Even when implemented, the application of "extraordinary measures" to improve recruitment was recognised to come at the "expense" of other MoD research establishments, and was therefore deemed not sustainable in the long term.[132]

A widely held opinion of many officials was that they did "not see any way of solving the general problem without an overall substantial improvement in Civil Service pay and… [they did] not envisage this coming about."[133] This was not unfounded, given that any pay increase for industrials would likely have to be matched with a commensurate raise for non-industrials to avoid strikes. Management was acutely aware of "the need to produce terms that will be acceptable to [the] Trades Union Side… on which the majority voice lies with the non-craft unions."[134] Half measures could therefore be counterproductive - a minor pay increase could be rejected by the industrials' union, while inciting "the non-industrial side [who] are refusing to cooperate."[135] A further fear from some MoD officials was that the safety situation at AWRE was being cynically exploited by the skilled labourers to extract better terms.[136] As a result of the above factors combined, the Treasury proved reluctant to approve additional funds to remedy the situation as John Biffen (newly appointed Chief Secretary to the Treasury) wanted to be "absolutely certain that all other possible avenues for resolving the problem have been fully examined" before extra capital was committed.[137]

While the idea of paying an increased salary to workers handling fissile material within AWRE gained traction, it faced its greatest resistance from the UKAEA. From the UKAEA's perspective, it was unfair that their workforce would not benefit from a special pay increase for handling fissile material, whereas AWRE's workforce would. Despite clarification it was for handling metallic plutonium (a niche nearly exclusively fulfilled by AWRE), the UKAEA claimed that nearly half of their 13000 strong workforce should receive the benefit.[138] Given that it was already difficult for AWRE to obtain approval for its own proposed pay increase, which even by the Treasury's

[130] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 29/06/1978 & TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 14/06/1978
[131] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 14/06/1978
[132] TNA, DEFE19/155, AWRE Manpower, 10/09/1979
[133] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 14/06/1978
[134] TNA, DEFE19/163, Titled - 'The Paper', 14/06/1978
[135] TNA, DEFE19/155, Pay of Industrials at AWRE Report, 06/07/1979
[136] TNA, DEFE19/163, Ministerial Committee on Economic Strategy, Sub-committee on Pay negotiations, 09/1978
[137] TNA, DEFE19/155, Pay of Industrials at AWRE - Biffen to SofS, 13/07/1979
[138] TNA, DEFE19/155, Pay of Industrials at AWRE, 24/07/1979

commentary was "minimal in relation to the importance and size of the programme," expanding the proposed benefit to such a degree would make it even more unpalatable to the government.[139] Resistance within government to AWRE's pay increase was therefore rightly premised on the idea that once special nuclear related allowances were afforded, "they tend to spread, both in scope and geographically."[140]

In terms of countering these objections, the repeated position of AWRE was that the situation was so serious as to require extraordinary measures. From May 1978, officials noted that "an early general solution is imperative if AWRE is to remain viable… [and] there is every indication that the position is deteriorating further."[141] Macklen repeatedly asserted the fragility of the deterrent. He stated that "if HMG wants a deterrent… they must be prepared to pay the ongoing rate for skilled labour in the Reading area. We would have been better off had we left AWRE in the UKAEA."[142] Macklen insisted that "maybe a very special look should be taken at the allowance position" at AWRE.[143] This was mirrored in AWRE management documentation from July 1979 that stated:

> *"If the loss of craftsmen cannot be reversed, and if the essential recruitment to implement Pochin cannot be met, then the continued operation of our present strategic deterrent will be at risk: the Chevaline improvement programme cannot be continued at all and all ideas of TNF modernisation and successive Polaris system work must be abandoned. Once the AWRE radio-active facilities can no longer be operated we cannot produce new warheads, nor can we investigate maintenance problems in the existing warhead stock. The situation could arise where we are not able to guarantee the reliability or safety of the stockpile. The option of using industry or contract labour is not open to us in the nuclear warhead field."*[144]

In addition, the "unique" nature of the Aldermaston facilities was stressed, and how the "best" workers were being lost.[145] The starkness of these warnings came as AWRE approached a critical time in the Chevaline production programme. If delivery of the complete system (submarines, missiles and warheads together) was to occur on schedule in 1981 then production had to be resumed immediately. Officials' warnings conveyed that "there is absolutely no time in hand."[146] As

[139] TNA, DEFE19/155, Pay of Industrials at AWRE - Biffen to SofS, 13/07/1979
[140] Ibid.,
[141] TNA, DEFE19/163, Industrial Labour at AWRE Aldermaston, 05/1978
[142] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 25/05/1978
[143] Ibid.,
[144] TNA, DEFE19/155, Pay of Industrials at AWRE, (n.d.)
[145] Ibid.,
[146] Ibid.,

a result, any negative consequences for the wider civil service, UKAEA or even the rest of AWRE had to be discounted. AWRE management warned that "we cannot wait for such theoretical possibilities to be resolved: we need to advertise now with higher rates of pay."[147]

In terms of countering the UKAEA's objections, Macklen retorted that "the brutal fact is that unless we re-start the AWRE production line we might as well cancel Chevaline and all other plans for nuclear warheads. Again brutally it wouldn't matter much if the AEA had a long industrial dispute."[148] David Cardwell, Aldermaston's Director was in agreement; in June 1978 he warned that "we thus live on the edge of a precipice and it would be all too easy for some incident to push us over."[149] Despite these warnings, the MoD was still warning in July 1979 that the situation was "critical," and if work did not resume within fissile handling areas by September 1979, delays would be inevitable.[150]

These repeated citations for the potential for nuclear weapons 'uninvention' were clear attempts to overcome civil service intransigence. Rather than happening gradually with the slow loss of scientific expertise, the loss of production capability posed the greatest potential for Britain's nuclear capability to become inoperable in a relatively brief period. By highlighting the loss of these 'unique' facilities and the loss of the particularly 'skilled' workers, their irreplaceable nature was highlighted. Nonetheless, without immediate remedies, the situation continued to deteriorate into 1979: on 1st July 1979, the craftsmen deficiency was 38% below the "required" complement to continue the warhead programme and raise health and safety standards.[151] In September 1979, AWRE had to recruit 950 extra staff just to rectify the "current situation."[152]

Solutions: Recruitment & Retention

In terms of alleviating the present situation, Aldermaston returned to improving recruitment and retention, iteratively repeating a cycle that had occurred since the 1940s. This first manifested in 1979 with the recognition that "the industrial situation…[was] intractable until, or unless, the

[147] Ibid.,
[148] TNA, DEFE19/155, Pay of Industrials at AWRE, 24/07/1979
[149] TNA, DEFE19/163, Letter - Cardwell to Broadbent, 14/06/1978
[150] TNA, DEFE19/155, Pay of Industrials at AWRE, (n.d.)
[151] Ibid.,
[152] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979

Government comes with some reasonable pay offer."[153] This resulted in a near 30% increase of civil service labourers' wages in July 1979, but this was still below average pay in the private sector.[154]

To compensate, a second extra "Aldermaston Special Allowance" was authorised in April 1979, amounting to £15 per week for workers handling fissile material.[155] While this benefit was seen as a positive measure by AWRE's management, it was judged that "by itself, this allowance was clearly inadequate to stop the manpower drain."[156] The idea of ring-fencing this additional bonus to only plutonium workers was intended to incentivize labourers already working at AWRE to internally transfer.[157] Promoting internal transfers of staff was important as improving recruitment would not remedy the situation fast enough. Recruitment was never a quick process at AWRE due to security clearance processing taking time.[158] Nonetheless, this fissile material handling bonus appears to have had a negligible effect as it "resulted in only one [internal transfer] applicant" by June 1979.[159]

A further proposed initiative was a productivity scheme, wherein efficiencies introduced by labourers could be rewarded "by up to £6.50" a week, but this was still under negotiation.[160] Even with all of these benefits combine, MoD officials noted in September 1979 of the need to "recognise recruitment realism" due to the ongoing economic situation and manpower shortage within the civil service.[161] Francis Pym believed that the only effective solution in the long term was a "bigger basic pay packet" at Aldermaston.[162]

In addition to remedying the pay situation, AWRE considered triaging its production efforts. This would involve "spreading the available effort more thinly over most of the Establishment's tasks with consequent delays and omissions."[163] Ironically, management noted that "It is disturbing that some of these items relate to the current safety improvements of the operations at AWRE."[164] In 1979, Peter Jones, then deputy director of Aldermaston noted that "we will consider "campaign" working of A.45 and A1.1."[165] Other less essential areas of work were to be halted if required.[166] In

[153] TNA, DEFE19/163, Chevaline Project at Aldermaston, 04/08/1978
[154] TNA, DEFE19/155, Pay of Industrials at AWRE Report, 06/07/1979
[155] TNA, DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[156] Ibid.,
[157] TNA, DEFE19/155, Pay of Industrials at AWRE, (n.d.) & TNA, DEFE19/155, Industrial Pay - Aldermaston, 30/07/1979
[158] TNA, DEFE19/155, Pay of Industrials at AWRE Report, 06/07/1979
[159] Ibid.,
[160] Ibid.,
[161] TNA, DEFE19/155, AWRE Manpower, 10/09/1979
[162] TNA, PREM19/14, Chevaline, 01/11/1979
[163] TNA, DEFE19/163, Implications of Shortage of Industrials at AWRE Aldermaston, 10/08/1978
[164] Ibid.,
[165] TNA, DEFE19/183, Critical Craft Labour Skills at AWRE, 04/01/1979
[166] Pyne, (2004), p.G-12

terms of the order of reductions considered in 1978, it is unsurprising that AWRE's non-nuclear programmes would be reduced first, followed by lower priority nuclear work, such as work on tactical nuclear weapons.[167]

Through a combination of the above factors, the staffing situation at AWRE appears to have gradually improved in 1980. Francis Pym wrote to Margaret Thatcher on 18th March 1980 that while the situation at Aldermaston "remains an area of concern… [and] of critical importance," "there has been some improvement in the staffing situation."[168] By November 1980, the Assistant Chief Scientific Adviser (Nuclear) briefed the Cabinet Defence Committee that "In fact we are recruiting quite nicely at the moment. We have begun to turn the corner as far as net increases of effort are concerned in the relevant skills in the establishment."[169]

Nonetheless, the closure of fissile material handling facilities at Aldermaston for three and a half years due to safety concerns had caused considerable delays to production and the subsequent fielding of Chevaline.[170] This had been evident from 1979 onwards, when Francis Pym informed the nuclear weapons sub-committee MISC 7 on the in November that it was "now clear that production delays due to shortage of staff at Aldermaston and Burghfield make it impossible to hold to the outload dates [of Chevaline] as originally planned."[171] While progress was made with the staffing situation at Aldermaston in 1980, the plutonium handling facilities only resumed operation in "January 1981 and even then, some of the remedial work was still in progress."[172] Given the safety situation had only been expected to last several months initially, it was unsurprising that the delays incurred in combination with the staffing situation meant that continuous deployment of the Chevaline system was delayed until late 1982.[173]

Greater Autonomy: Back to the UKAEA?

Given the tumult in AWRE because of its apparent inability to retain its skilled workforce, the SofS revisited the question of how to administer Aldermaston. While the transition to the MoD had

[167] TNA, DEFE19/163, Implications of Shortage of Industrials at AWRE Aldermaston, 10/08/1978
[168] TNA, PREM19/159, Chevaline, 18/03/1980
[169] Defence Committee, Fourth Report, Session 1980–1981, Strategic Nuclear Weapons Policy, Report and Minutes of Evidence, 20/04/1981, p.169
[170] Spinardi, (1997), p.568
[171] TNA, PREM19/14, Chevaline, 01/11/1979
[172] Pyne, (2004), p.G-10
[173] TNA, PREM19/14, Chevaline, 01/11/1979 & Stoddart, (2) (2014), p.105

been to increase the political control that could be exerted on the weapons establishment, the processes that had led to the skilled labour crisis of 1978-1979 through the reduction in employment flexibility under the MoD were evident to contemporaries. For example, on 25th May 1978, Macklen bluntly stated that it would have been better if AWRE had been left in the UKAEA.[174] The issue was raised on 22nd September 1980 by the incoming Conservative SofS, Francis Pym, who asked "particularly in light of the decision… [to procure] Trident, how we can most efficiently carry out our defence nuclear programme."[175] He tasked his officials to study whether AWRE should be placed back under UKAEA control amongst other options.[176]

Aside from retaining AWRE in the MoD or returning it to the UKAEA, this review raised the possibility of contractorisation – that the private sector would operate the establishment's management. Consideration of this approach appears to have emanated from partially replicating the US model, wherein the Department of Defence specified their requirements to the Department of Energy, whom in turn tasked their privately operated non-profit laboratories delivering nuclear weapons.[177] It was noted that this approach was not without critique and that there existed multiple sub-options to contractorise or privatise AWRE if that was the preferred option.[178]

The apparent attraction for these more privatised models of management was to introduce new expertise on overseeing complex production lines. A focus on production rather than research was believed to have become increasingly important with every successive generation of nuclear weapons systems.[179] This consideration was of particular importance, as from August 1979 onwards, the Director of AWRE also became Deputy Chief of Defence Procurement (Nuclear). With this new role, he also controlled the two Royal Ordinance Factories (Burghfield and Cardiff) which manufactured nuclear weapons components. Although Burghfield and Cardiff were not officially integrated into AWRE until 1987 (henceforth renamed AWE – Atomic Weapons Establishment), it marked a further rebalancing away from research and towards production and stewardship.[180]

A reality recognised in the 1980 review of Aldermaston's management was that since the 1960s, AWRE had to deal with unpredictable "fluctuations in the flow of work."[181] As a result, AWRE had to "remain viable" by "accommodating… peaks and troughs" by expanding and contracting the

[174] TNA, DEFE19/163, Skilled Industrial Labour at AWRE, 25/05/1978
[175] TNA, PREM19/2200, Pym to Secretary of State for Energy, 22/09/1980
[176] Ibid.,
[177] TNA, PREM19/2200, US Nuclear Weapons Organisations, (n.d.)
[178] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.)
[179] Ibid., It was believed that the UKAEA lacked this expertise. See also Committee of Public Accounts, Ninth Report, Session 1981–1982, Ministry of Defence: Improvement to the Polaris Missile System, 17/03/1982, p.13
[180] DEFE19/155, Background Information on AWRE for PS Civil Service Department, 09/1979
[181] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.)

workforce in a sustainable way.[182] This could be achieved through one of the key benefits contractorisation potentially offered: departing from the civil service would allow greater flexibility. Salaries could be allocated on an individual basis, rather than being restricted to prescribed bands.[183] According to contemporaries, this could "prove more expensive than at present but needs to be set against… reducing the risk of delays in projects."[184]

Despite the potential benefits of moving towards a privatised model highlighted by the Study Group, Pym decided against proceeding in 1981 with any of the examined alternatives. The potential to disrupt Trident development early on proved decisive. In addition, the privatisation of the nuclear programme was judged too politically costly and would have recently contradicted the Conservative's decision to move AWRE to the MoD.[185] Ultimately, with the staffing problems seemingly mostly alleviated by 1982, these difficulties were dismissed as a temporary industrial dispute, so no systematic change took place during the early period of Thatcher's administration.[186] As will be seen, many of the institutional problems linked to staffing issues would return to prominence in the 1980s.

A New Project: Trident

Labour's 1974 commitment not to replace Polaris and decision to produce Chevaline in 1978 may have been expected to introduce a pause in acquiring new strategic systems into the 1980s.[187] However, given the timeframes of development involved and the belief in the need to ensure the ongoing deliverability of the 'Moscow Criteria,' a 'Restricted Group' of Cabinet Ministers examined potential future nuclear systems from November 1977 onwards.[188] This process resulted in the production of the Duff-Mason Report, which recommended the acquisition of the US Trident C4 system.[189] Although the contemporary history of AWRE/AWE from 1978 to 1993 is poorly covered in the secondary literature, the following section will test hypotheses inductively generated from primary sources. It will demonstrate through the interlinked processes that concerns over knowledge management complicated decision making for Polaris successor systems, that conditions

[182] Ibid.,
[183] Ibid.,
[184] Ibid.,
[185] Ibid.,
[186] TNA, PREM19/695, Chevaline, 17/06/1982
[187] Stoddart, (2) (2014), p.37
[188] Ibid., p.37
[189] Ibid., p.74

at Aldermaston posed lingering problems in the 1980s and that the Thatcher government's solution was to privatise AWE's management.

The Challenge of Uniqueness

In the 1960s, AWRE's advocates used the need to retain skills to justify the Polaris Improvement Programme. In contrast, from 1978, successive governments' nuclear weapons policy decisions were limited by AWRE's capabilities (in both capacity and expertise). Both the Labour government of 1978-1979 and Thatcher's new Conservative government, policy emphasised avoiding acquiring a system that only Britain would use. This was based on the expense of producing Chevaline and retaining Polaris missiles in service alone; 'uniqueness' was highly expensive and to be avoided if at all possible.[190] Not only did this diminish the appeal of Trident alternatives (such as a cruise missile option advocated by David Owen or an indigenous ballistic missile programme), but also provided the "principle argument" to pursue the D5 rather than C4 missile. The decision to acquire a system that was beyond what was "sufficient for our deterrent need" was seen as necessary to "retain commonality with the US, and thereby avoid the penalties of uniqueness."[191]

However, this upgrade to the D5 posed a further dilemma for nuclear policy based on the capacity of Aldermaston. On the one hand, acquisition of the D5 avoided the potential need to upgrade a C4 based capability half way through its life cycle to ensure its future effectiveness against ABM defences.[192] This was a serious concern that was countenanced, and one to be avoided due to the aforementioned risk of uniqueness and technical risk.[193] On the other hand, how many warheads to produce for the D5 was also an issue. Each D5 missile had the capacity to carry 14 warheads, and with three submarines with 16 missile tubes in operation, this could require up to 672 warheads to fully equip the proposed Trident programme.[194] Although such a large number of warheads would be excessive for British deterrence needs and hugely costly, R.A. Miller noted that certain officials were briefing for a high warhead figure on the basis of the "maximum insurance against ABM

[190] TNA, DEFE19/275, Factors Relating to Further Consideration of the Future of the UK Nuclear Deterrent – Annex C, TNA, PREM19/417, Defence Open Government Document 80/23 - The Future UK Strategic Nuclear Deterrent Force, 15/07/1980 & TNA, PREM19/694, The United Kingdom Strategic Deterrent, 11/01/1982
[191] TNA, AIR8/2846, UK Strategic Deterrent Force, (n.d.)
[192] Stoddart, (2) (2014), p.230-244, TNA, DEFE69/768, UK Strategic Deterrent, (n.d.)
[193]HM Government, Defence Open Government Document 82/1, "The United Kingdom Trident Programme," 03/1982, TNA, PREM19/159, Chevaline, 02/03/1982 & TNA, DEFE19/275, Future of the UK Nuclear Deterrent - Part III - System Options, 08/12/1978
[194] TNA, AIR8/2846, Chiefs of Staff Meeting, 28/07/1981. Up to 896 with four submarines.

defence."[195] The potential for such a programme prompted concerns over Aldermaston's capacity.[196] The number of warheads to equip Trident had to be matched against Britain's future ambitions for other nuclear systems. This was because "maximum AWRE output for 1987/88" was "60 warheads per year."[197] To produce a new sub-strategic weapons system, capacity had to be available at Aldermaston in the 1990s, before the WE-177 became inoperable.[198] Given the above warhead figures, Trident production alone would preoccupy Aldermaston for a decade.

The fact that Aldermaston may struggle with Trident production was public knowledge; the safety problems raised by the Pochin inquiry had already revealed the staffing and capacity problems at Aldermaston. Peter Hennessy wrote an article for the Times in May 1980, titled "Trident Deterrent may be Toothless" that highlighted how a lack of recruitment could endanger the Trident Programme. [199] John Cartwright, a Labour MP, stated his belief in July 1980 that Trident warhead production "would strain [the] manufacturing capability [of Aldermaston]… very considerably," but the challenges were not insurmountable.[200] The Defence Select Committee concurred, concluding that producing numerous MIRV warheads "will indeed cause difficulties over the next 10 to 15 years," but they too believed that AWRE could manage.[201]

Despite the problems that AWRE had experienced in 1978-1979 due to a lack of staff, the establishment's advocates did not utilise the uninvention argument to the same extent as during the 1960s. Nonetheless, with the nearing completion of Chevaline, it was inevitable that Aldermaston's leadership had given some thought to new projects. Colin Fielding (Director of Aldermaston and successor to Newley) testified to the Defence Committee in 1980 that the "generation of…[nuclear] capability is a very difficult thing to generate and it probably could never in practice be re-generated once taken away."[202] With the committee accepting this logic, the maintenance of even the present capability once again justified further developments.[203] This was apparent to Miall, who on the basis of this testimony claimed in 1987 that "directors of Aldermaston have persisted in presenting the

[195] TNA, AIR8/2846, MISC 7 - Chiefs of Staff Submission, 06/10/1981
[196] HM Government, Defence Open Government Document 82/1, "The United Kingdom Trident Programme," 03/1982 & Stoddart, (2) (2014), p.187
[197] TNA, AIR8/2846, Chiefs of Staff Meeting, 28/07/1981
[198] TNA, AIR8/2846, Chiefs of Staff Meeting, 28/07/1981 & TNA, AIR8/2846, Costs of the Strategic Nuclear Deterrent, (n.d.)
[199] Hennessy, (1980)
[200] Defence Committee, Session 1979–1980, Strategic Nuclear Weapons Policy, Minutes of Evidence, 09/07/1980, p.32
[201] Ibid., p.23
[202] Defence Committee, Fourth Report, Session 1980–1981, Strategic Nuclear Weapons Policy, Report and Minutes of Evidence, 20/04/1981, p.176.
[203] Ibid., p.59

government with a choice between developing new nuclear weapons and the gradual atrophy of Aldermaston's capabilities to make new weapons."[204]

That the weapons establishment needed a further programme to sustain itself may have been implicit; Lawrence Freedman wrote in 1981 that "without a Trident programme or something similar, it is difficult to see how the Atomic Weapons Research Establishment at Aldermaston, responsible for warhead design and development, or the Royal Ordnance Factory at Burghfield, responsible for warhead production, could be kept in existence with a qualified staff."[205] A further limitation on citing the vulnerability of AWRE was that it had to present itself as being able to conduct the Trident programme. Rather than reflecting Fielding's "known pessimist" beliefs on the capacity of AWRE, on the basis of presented testimony to the Defence Select Committee, the panel believed in 1981 that "as far as the Atomic Weapons Research Establishment at Aldermaston is concerned, it does not appear that shortfalls in skilled labour will hold up the programme."[206]

An Ongoing Staff Crisis

With negotiations with the Reagan administration and subsequent Cabinet discussions concluded, the decision to proceed with Trident D5 was announced to Parliament in March 1982.[207] Despite this public commitment and earlier protestations of AWRE's capability, problems of adequately staffing AWRE to fulfil the Trident programme re-emerged from 1983 onwards. From "the inception of the monthly report[ing to the SofS] in August 1983" on the progress of the Trident programme, delivering the nuclear warhead and re-entry body "aspect of the programme [by AWRE]…[had] been…[categorised as a] minor weakness."[208] This was because a large recruitment effort was needed to rebuild the establishment's manpower from its nadir to levels necessary for a new major research and development project.[209] As with previous recruitment efforts of the period, the rate of staff increase "barely kept pace with… natural wastage."[210] As a result of these early signs that progress was not proceeding smoothly at AWRE, the MoD's Controller of R&D Establishments, Research and Nuclear (CERN) took an increasingly proactive but unwelcome role in imposing new

[204] Miall, (1987), p.15
[205] Freedman, (1981), p.82
[206] Defence Committee, Fourth Report, Session 1980–1981, Strategic Nuclear Weapons Policy, Report and Minutes of Evidence, 20/04/1981, p.xvii & Stoddart, (2) (2014), p.187
[207] Stoddart, (2) (2014), p.201
[208] TNA, DEFE13/2012, Trident Monthly Report - February 1985, 06/03/1985
[209] Ibid.,
[210] Ibid.,

practices at the establishment. This resulted in an increasingly tense dispute between CERN and AWRE in 1983 and 1984 over the "needs of sound… project management practice" to be effectively implemented at AWRE.[211] CERN wanted AWRE to implement their interpretation of the recommendations of the 1966 Downey Report, which advocated splitting defence projects up into phases and incremental deliverables, with the results passed back to a headquarters, then being used to monitor and evaluate progress.[212] This was intended to provide greater oversight to the MoD, which would help improve "the position compared to Chevaline… [where there was] no network… to control [the] intramural programme" at AWRE.[213]

Although implementing greater external oversight was reasonable given the Chevaline experience, the discussion returned to the issue of staffing levels at the establishment. AWRE "rejected… [the move as] in their opinion the scheme could not be implemented without unacceptable disruption to the project."[214] This was due to a "real world lack of resources," but also because the fundamental cause of the problems at AWRE was a disproportionate loss of engineering staff, for which no readjustment in project management would fix.[215] In turn, CERN believed that AWRE's dysfunction in meeting Trident goals was due to it being unable to match recruitment "realism" with plausible deadlines.[216] Targets produced by AWRE and provided to the MoD had been set on where the establishment would have reached had they had their full complement of staff, rather than the strength they had in reality.[217]

This raised the prospect of significant "slippage:" if key milestones were missed, AWRE would hold up other areas of the programme such as underground tests and the outfitting of submarines, which would prove extremely expensive and delay Trident's entry into service.[218] Although AWRE exhibited an apparent "blatant disregard of [Trident] HQ needs," CERN conceded that the inability to apply better practices was exacerbated by the "outflow of experienced staff"

[211] TNA, DEFE72/450, AWRE Management and Headquarters Monitoring of the Trident RBA Development Programme at AWRE, 11/12/1984
[212] TNA, DEFE72/450, Comments on Monitoring Progress and Resource Utilisation on Trident, 04/01/1984 & TNA, DEFE72/450, The DCP and Downey Procedures, (n.d.)
[213] TNA, DEFE72/450, AWRE Trident Programme and Financial Controls, 13/01/1984
[214] TNA, DEFE72/450, Comments on Monitoring Progress and Resource Utilisation on Trident, 04/01/1984
[215] TNA, DEFE72/450, AWRE Cost Plan for Trident, 23/09/1983 & TNA, DEFE72/450, Trident RBA Development Programme, 06/06/1984
[216] TNA, DEFE72/450, AWRE Management and Headquarters Monitoring of the Trident RBA Development Programme at AWRE, 11/12/1984
[217] Ibid.,
[218] TNA, DEFE72/450, AWRE Management and Headquarters Monitoring of the Trident RBA Development Programme at AWRE, 11/12/1984

needed to effectively manage the project.[219] Therefore, from both CERN and AWRE's perspectives, the inability to recruit and retain staff across the establishment at all levels and roles was eroding AWRE's ability to conduct the Trident programme.

By December 1984, an apparent consensus had been reached between CERN and AWRE that there was now a significant risk for Trident 'slippage' due to the staffing situation.[220] Between September 1984 and February 1985, "only 40% of the trials [experiments at AWRE] scheduled for completion had been completed and 48% of the trials scheduled to start have started."[221] These delays, attributed to "facility constraints and staff shortages" contributing to the postponement of a major milestone in development of the programme - the warhead design 'freeze.'[222]

By February 1985, Admiral John Grove (then acting as Chief Strategic Systems Executive - CSSE) was warning the SofS that the status of the AWRE component of the Trident programme was close to being considered a "major weakness" due to the "deteriorating situation" in regard to recruiting and retaining manpower.[223] Grove warned that "the longstanding concern regarding the recruitment of personnel at the AWRE is assuming a more serious threat to the Trident warhead production programme and the matter is now being handled at the highest official level."[224] This was because a significant increase in staffing was needed at Aldermaston to commission and operate the plutonium component production A90 facility, in addition to continue to develop the warhead. In February 1985, AWRE was understaffed by nine percent for "Technical grades, science grades and craftsmen;" In some "critical" areas, the manpower shortage was "near 30%."[225] This staffing shortage "was despite intensive use of Civil Service recruitment methods and internal management action."[226] In terms of the impact of the staffing situation on the timetable for the programme, the original schedule had to be abandoned; AWRE was tasked with redeveloping their warhead programme based on their actual rather than specified strength.[227]

[219] TNA, DEFE72/450, AWRE Management and Headquarters Monitoring of the Trident RBA Development Programme at AWRE, 11/12/1984 & TNA, DEFE72/450, Elphick to Dracott, 14/08/1984
[220] TNA, DEFE72/450, AWRE Management and Headquarters Monitoring of the Trident RBA Development Programme at AWRE, 11/12/1984
[221] TNA, DEFE72/450, Development Report - Annex A, 28/03/1985
[222] Ibid.,
[223] TNA, DEFE13/2012, Trident Monthly Report - February 1985, 06/03/1985
[224] Ibid.,
[225] TNA, DEFE72/450, Development Report - Annex A, 28/03/1985 & National Audit Office, Ministry of Defence and Property Services Agency: Control and Management of the Trident Programme, 01/07/1987, p.18
[226] National Audit Office, Ministry of Defence and Property Services Agency: Control and Management of the Trident Programme, 01/07/1987, p.18
[227] TNA, DEFE72/450, Development Report - Annex A, 28/03/1985

Without amelioration, the situation was deteriorating. In March 1985, AWRE delayed a review stage for the Trident warhead by a further two months, so that it was five months behind schedule. The CSSE's report stated that "these delays have been caused by a combination of equipment problems and staff shortages at AWRE."[228] To rectify the situation, the Minister for Defence Procurement (then Adam Butler), submitted a series of recommendations in April 1985 to a Treasury review that included "a number of administrative measures and financial inducements to improve the attractions of AWRE both to existing staff and to encourage external and internal recruitment."[229] While these were under consideration, the manpower situation at AWRE remained "virtually static," which given the existing deficit, was a worrisome sign.[230] Nonetheless, this situation persisted; in July 1985, the CSSE's report noted that "very soon the manpower shortfall will have a direct effect on the Trident Warhead development programme."[231]

The seriousness of the situation meant that Special Pay Additions (SPA) received prompt approval for scientists and engineers in 1985.[232] However, the Treasury prevaricated in granting awards to industrial grades, generating "intense ill-feeling" and strike action.[233] When this situation was rectified with a small pay award, administrative staff also protested their omission producing "some very ugly scenes indeed."[234] Despite the relatively small amounts of money involved, industrial strife persisted until 1987, generating "a most deplorable effect on… morale… recruitment and retention."[235] Nonetheless, Michael Quinlan stated in 1988 that the SPA programme "helped AWE in a substantial recovery from a dire situation."[236] While there had been a specialist shortfall of 9% in February in 1985, this had been reduced to 4.7% by April 1987.[237] In addition to SPAs, AWE's management specifically "identified 60 vacant posts considered critical to the Trident Programme" in 1986 and heightened their recruitment efforts for these posts.[238] By April 1988, all but five of these posts had been filled, ensuring there were no critical skill shortages affecting development of the Trident warhead.[239]

[228] TNA, DEFE13/2012, Trident Monthly Report – March 1985, 01/04/1985
[229] TNA, DEFE13/2012, Trident Monthly Report – May 1985, 05/06/1985
[230] TNA, DEFE13/2012, Trident Monthly Report – April 1985, 03/05/1985
[231] TNA, DEFE13/2012, Trident Monthly Report – June 1985, 05/06/1985
[232] TNA, DEFE72/456, Draft Letter to HM Treasury - marked E20, (n.d.)
[233] Ibid.,
[234] Ibid.,
[235] Ibid.,
[236] TNA, DEFE72/456, Staffing of the Atomic Weapons Establishment, 09/08/1988
[237] Defence Committee, Third Report, Session 1987–1988, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 11/05/1988, p.xxiii
[238] TNA, DEFE72/456, Manning at AWE, 04/1988
[239] Ibid.,

Although the SPA awards "initially… [had] a most beneficial effect on recruitment… of engineers and scientists," this was not the case by late 1987.[240] CERN noted that "Aldermaston and Burghfield manpower peaked (below target) in late 1987 and has been declining rapidly ever since, with high turnover exacerbating the net loss."[241] This level of turnover at the establishment was seen as unsustainable, as new staff were leaving before they were competent to handle fissile material and veteran staff were continuing to retire too.[242] This was because any pay increases to staff between 1985 and 1988 were deducted from the SPA; as result, private industry became more attractive to staff as the local economy thrived. [243] This was a grave situation for AWE as it was delaying the construction of the A90 facility which would be used to produce plutonium components for the Trident warheads.[244]

In January 1988, the situation became public knowledge when the Independent ran two articles highlighting how Trident was falling behind schedule, with "staff shortages… [being] the main constraint on production."[245] This was critical as production of fissile components began in January 1988 at Aldermaston, two years behind the initial schedule offered to the Defence Select Committee in 1980.[246] Michael Quinlan noted that on 11th May 1988, the Prime Minister had "said that the growing shortfall of staff at AWE was disturbing, and that urgent consideration should be given to means of redeeming the situation."[247]

As a result, the Chancellor and SofS were tasked under the direction of Quinlan to find solutions. At a minimum, staff were needed to fill "179 Specialist and 100 Craft posts" 'hard' vacancies "assessed by AWE as being necessary for Trident."[248] Through the course of 1988 and 1989, a number of measures were suggested and implemented in an attempt to rectify the situation. Of interest to this study is that many of these schemes were remarkably similar to those first offered to rectify issues with the HER project between 1947 and 1952.

The primary measure to improve the manpower situation was the "urgent" need to improve pay at AWE.[249] Although other paths to improve recruitment and retention were concurrently

[240] TNA, DEFE72/456, Draft Letter to HM Treasury - marked E20, (n.d.)
[241] TNA, DEFE72/456, AWE Foulness: Claim for Special Pay Award, 09/01/1989
[242] TNA, DEFE72/456, Industrial Relations at AWE - Brief for Sir Robin Butler, (n.d.)
[243] Urban, (1988) & TNA, DEFE72/456, Draft Letter to HM Treasury - marked E20, (n.d.)
[244] Urban, (1988)
[245] Ibid.,
[246] Defence Committee, Third Report, Session 1987–1988, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 11/05/1988, p.xxiii
[247] TNA, DEFE72/456, Staffing of the Atomic Weapons Establishment, 09/08/1988
[248] TNA, DEFE72/456, AWE Manning: Monthly Report for July 1988, 26/07/1988
[249] TNA, DEFE72/456, AWE Manning, 15/07/1988

pursued, Quinlan acknowledged that the "urgent and growing" risk of delay meant that "we cannot responsibly wait for… non-pay measures… [to] yield dividends on a scale beyond experience or likelihood."[250] The acknowledgement that it had to be through both generous and universal SPAs was acknowledged by Michael Quinlan who believed that the MoD had "learnt the hard way in 1985-1987."[251] This was resisted by the Treasury who believed that "management weaknesses" were being "temporarily camouflaged by an extravagant use of pay additions;" to overcome this intransigency, AWE had to pledge to conduct and implement manpower efficiency studies.[252] Other government research establishments were concerned that the SPAs would allow AWE to "poach" their staff.[253] Nonetheless, by October 1988, a range of bonuses had been agreed with the Treasury with varying awards dependant on grade and skill scarcity.[254] As early as November 1988, AWE believed that "there is some slight evidence… that the… Special Pay Additions may be beginning to produce the desired effect."[255]

With pay awards addressed, recruitment efforts were redoubled. This included extensive advertising campaigns in print news, radio and open days to advertise vacancies at AWE.[256] Unfortunately for the establishment and despite many replies, the results were "frankly disappointing… for the money and time invested…. The quality of those who actually applied was, overall, very poor."[257] Other measures that had previously been used included recruiting defence service personnel approaching retirement for AWE.[258] Similarly, approaches were made to UKAEA and Royal Ordnance Factory staff who were set to be made redundant.[259] One major innovation was to increase the flexibility of employment conditions at AWE; these included offering part time or short service contracts and the possibility of extending employment five years beyond the normal retirement age of sixty.[260] These changes were important as AWE had identified a "bulge" in its "age profile" as many of its highly experienced staff were nearing retirement. There was clearly a concern that if new recruits were not found soon, this cohort would retire without transmitting their knowledge to the next generation.[261]

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[250] TNA, DEFE72/456, Staffing of the Atomic Weapons Establishment, 09/08/1988
[251] Ibid., the AWE director also acknowledged this. See TNA, DEFE72/456, Staffing of AWE, 15/09/1988
[252] TNA, DEFE72/456, Staffing of the Atomic Weapons Establishment, 20/09/1988
[253] TNA, DEFE72/456, Staffing of the Atomic Weapons Establishment, 10/10/1988
[254] TNA, DEFE72/456, AWE, 14/10/1988
[255] TNA, DEFE72/456, AWE Manning: Monthly Report for November 1988, 14/11/1988
[256] Ibid.,
[257] TNA, DEFE72/456, AWE Manning: Recruitment Advertising Campaigns, 20/10/1988
[258] TNA, DEFE72/456, PUS to CAS, 10/10/1988 & 291
[259] TNA, DEFE72/456, AWE Manning, 10/08/1988
[260] TNA, DEFE72/456, AWE Manning: Monthly Report for June 1988, 15/06/1988
[261] Committee of Public Accounts, Thirty-First Report, Session 1987–1988, Naval Warship and Weapons Procurement, 27/06/1988, p.27

As with the HER project in the early 1950s, the MoD was "aware that the availability of MoD houses is one of our best recruitment aids…It is essential that AWE should continue to have houses available to offer prospective recruits."[262] In direct contravention of general Conservative policy, publicly owned housing was retained in the Aldermaston area to ensure that this offer could be upheld.[263] Due to acknowledging that many of the new staff would have to move into the area, providing a reallocation bonus and correcting "the non-availability of housing" was essential as it was "becoming a constraint on recruitment."[264] In another similarity to the 1950s, further complaint from AWRE's management was that the process of acquiring security clearances for new staff was frustrating recruitment efforts.[265] Retaining and recruitment issues were proving to be persistently cyclical.

Contractorisation – An Enduring Solution?

The measures introduced in 1988 to improve recruitment and retention at AWE were enough to prevent a delay in introducing Trident into service. However, the "serious problems" at Aldermaston relating to staff shortages were threatening to undermine the projected 1992 second production batch of Trident warheads unless resolved.[266] Given that industrial problems had persisted at AWE throughout the 1980s, and that SPAs were temporary solutions, it is unsurprising that the Conservative government's view was that the establishment's "inefficiency had reached the point" where it had to be addressed.[267] As had already been considered in 1980, a further cycle of institutional development was considered.

Reforms within the civil service framework appeared inadequate. An agreement was reached between the Institute of Professional Civil Servants Union and the MoD that theoretically allowed for some deviation from specified pay bands for recruiting staff with required skills at AWE.[268] However, as each case had to be passed onto the Treasury for approval, a MoD official

[262] TNA, DEFE72/456, AWE Manning, 10/08/1988
[263] Ibid.,
[264] TNA, DEFE72/456, AWE Manning: Monthly Report for February 1989, 15/02/1989
[265] TNA, DEFE72/456, AWE Manning, 15/07/1988 & TNA, DEFE72/456, AWE Manning: Monthly Report for June 1988, 15/06/1988
[266] Committee of Public Accounts, Thirty-First Report, Session 1987–1988, Naval Warship and Weapons Procurement, 27/06/1988, p.26-27 & Defence Committee, Ninth Report, Session 1989–1990, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 13/06/1990, p.xxiii
[267] Lawson, (2011), e-book – Chapter 57
[268] Defence Committee, Third Report, Session 1987–1988, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 11/05/1988, p.xxiv

testified to the Defence Select Committee in 1988 that this requirement meant that "we have no freedom."[269] A further effort to reform Aldermaston came with the appointment of Dr Thomas Mclean at Aldermaston, who reportedly was referred to by some staff as "slasher" for his efforts to drop ancillary projects to improve efficiency.[270] This move was further bolstered by a commitment made as a concession to the Treasury in 1988 in order to obtain the SPA, wherein AWE was to conduct further efficiency studies. [271] This resulted in a proposal for an "arbitrary" reduction from a titular strength of 7100 to 6400 in February 1989 based on an external review by the Industrial Society.[272] As with the Kings Norton Inquiry, although the report was able to make recommendations, the exact figures came without "detailed credibility to them."[273] Without enough guidance, Margaret Thatcher tasked Francis Tombs (chairman of Rolls Royce) to examine the organisation of AWE.[274]

After an investigation lasting from July to September 1989, Tombs central recommendation was that "if the deadlines for the Trident programme were to be met, Aldermaston must get away from a situation where the workforce were in control to one where management was in control. The warhead programme needed professional manufacturing management and action to detach the work force from old practices and rigid pay-scales."[275] The report identified this management weakness stemming from "production in AWE…[being] run by scientists."[276] This reportedly manifested in a disinterest in the practicalities of warhead production, but also "low expectations of effectiveness… in industrial relations issues…[which gave rise to] unsatisfactory practices including: lateness and early leaving; unauthorised tea breaks and visits to the canteen; exploitation of trivial safety issues… and opposition to contractor presence."[277]

With the report readily accepted by Thatcher's government, implementation proceeded. Although it had initially been intended to institute contractorisation without legislation, this was found to be legally untenable.[278] Therefore, in December 1989, the initiative was announced in

[269] Ibid., p.4
[270] Urban, (1988)
[271] TNA, DEFE72/450, Manpower Requirements of AWE, 16/02/1989
[272] Ibid.,
[273] Ibid.,
[274] Hawkings, (2000), p.80
[275] TNA, DEFE72/573, AWE: Future Management, 26/10/1989
[276] TNA, DEFE72/573, AWE Production, Engineering and Support, A Review of the Study Group Activities 3 August - 16 September, 22/09/1989
[277] Ibid.,
[278] TNA, DEFE72/573, AWE Industrial Management - Sir Francis Tombs Report, 29/09/1989. A portion of the management was placed under the Hunting BRAE consortium before full contractorisation was implemented, but this was viewed only "as a limited 'stepping stone' to full contractorisation." TNA, DEFE19/506, Draft Letter from SofS to the Prime Minister, (n.d.)

Parliament.[279] The justification was "the need for increased production from 1992 for later Trident deliveries against the background of the keen demand for skilled labour in the Thames valley area, poses an increasing challenge, and one for which a greater production management capability is required."[280] Transition to contractorisation would provide the "greatest possible freedom to offer the terms and conditions needed to attract and retain the work force [they required]."[281] With the passing of the Atomic Weapons Establishment Act in 1991, management of AWE was transferred to Hunting-BRAE Ltd. in 1993.[282] As with the first transition to the UKAEA in 1954, another restructuring of the weapons establishment had been implemented based on retaining skill through more flexible employment.

Trickle Production: An Alternate Skills Based Approach

While Chevaline and Trident were the major concern of Aldermaston during this period, stockpile stewardship became an increasingly important preoccupation. The need to maintain nuclear weapons in the event of unforeseen technical problems was one of the key justifications for a large complement during the Kings Norton Inquiry.[283] Corrosion, radiolysis, the "out-gassing" of hydrogen isotopes and the obsolescence of electronics within warheads would mean that weapons would have to be constantly monitored, repaired and possibly replaced over time.[284] As the age of the weapons stored within the British arsenal increased, so to would the challenges involved in this process.[285] This was pertinent to the WE-177 system, as it had a "design life… [of] 8 years… subsequently doubled to 16… extended first to 20… [and then] 30 years is currently assumed for all weapons [in the 1980s]."[286] Entering service in 1966, the last WE-177s were only been withdrawn from service in 1998.

In order to overcome unknown problems involved in stockpile surveillance, all aspects of AWRE had to "maintain their skills at a high level" according to arguments forwarded in the late 1960s.[287] These anticipated but unpredictable problems could only be overcome if tacit knowledge

[279] Thomas King, HL Deb 05 December 1989 vol. 513 cc750-3
[280] Ibid.,
[281] Alan Clark, HC Deb 18 December 1990 vol. 183 cc183-185
[282] Office for Nuclear Regulation, (2017)
[283] TNA, DEFE19/98, Cost of Military Nuclear R&D in AEA Weapons Group, 15/11/1968
[284] Ibid.,
[285] Ibid.,
[286] TNA, DEFE25/678, UK Theatre Nuclear Weapons Successor System, (n.d.)
[287] TNA, DEFE19/98, Cost of Military Nuclear R&D in AEA Weapons Group, 15/11/1968

was maintained, so skills "must be fully exercised and new men must be trained on the job."[288] While major project work (such as Chevaline) was clearly one source of this exercise (and as seen in the previous chapter, a partial justification for the initiation of the project), it was recognised that a cheaper and more consistent source of maintaining tacit knowledge had to be found. This could also be achieved by up keeping a "steady trickle of production" of existing components to refurbish existing warheads. [289]

In explicit response to the Kings Norton report and the "need to keep a certain minimum range and quality of staff and facilities" in an operational state necessary for stockpile maintenance, a new work stream for WE-177 was introduced in 1970.[290] Even while new warheads for the WE-177 A and B variants were being manufactured, a process of continual refurbishment was initiated. This involved "trickle production of all key components and then destroying them, or… replacing old ones…from the stockpile."[291] However, the initial tranche of trickle production work "only operated for three years," before all resources were diverted back towards the Polaris Improvement Programme.[292] At this stage, the first tranche of WE-177s were still relatively new, so "trickle production was to keep up our expertise and had no [immediate] connection with stockpile reliability."[293] When a level of trickle production (alternatively referred to as 'continuous relifting') for WE-177 was resumed in the late 1970s, maintaining reliability was a greater concern. With WE-177 now expected to be in service until 1985, "specialised expertise" such as "tile filling" (a particular skill involved in casting the explosives used in the multipoint primary) had to be exercised, otherwise it would be lost.[294] Gradual refurbishment was therefore revived in "what Aldermaston called the 'Trickle philosophy'."[295] This involved replacing "about one tenth of the stockpile per year for final weapon assembly" for the WE-177 systems.[296]

There were however drawbacks to this approach. It was recognised that: *"The copy will not be exact in a perfectionist sense. No specification can entirely exclude the need for skill and interpretation; people and facilities change. Although these are exercised on old designs to some extent by trickle production, ultimately confidence in the re-manufactured warhead must rest on*

[288] Ibid.,
[289] Ibid.,
[290] TNA, DEFE13/925, Min 7, 09/01/1970
[291] TNA, DEFE13/925, Min 4, 09/01/1970
[292] TNA, DEFE19/240, Record of a Meeting with Dr Frank Press, 16/02/1978
[293] Ibid.,
[294] TNA, DEFE19/195, Estimates and 1979 LTC - Assumptions - WE177 Replacement, 11/07/1978. Loss of 'tile manufacturing' at ROF Burghfield was an area of concern that could have led to the premature withdrawal of WE-177 A & Cs. See also TNA, DEFE19/195, Extension of WE177B Life, 04/07/1977
[295] Walker, (2019), p.31
[296] Ibid., p.31

technical judgement that the changes from the version originally tested are not significant, rather than a faith that the processes and materials are identical."[297] Therefore, while a trickle approach retained expertise, it threatened degradation due to the "accumulation of change."[298] While for the most part, these would prove minor, such as new "bridge wire materials" and new "techniques for uranium welding," more substantial changes such as more inert explosives would prove problematic.[299] Accumulated changes could also build quickly; for the non-nuclear components of the system, a 1973 document noted refurbishments had resulted in "over 1000 modifications to the weapon as a whole." [300] While Macklen noted that only changes in the physics package mattered in this context, replicating the original specification would also eventually become problematic too.[301] Trickle production and refurbishment would also prove costly and difficult to implement as all the original manufacturing capabilities had to be retained at some level, but also that different components would age differently and must be replaced at varying times.[302] Nonetheless, this was seen still as preferable to periodic campaigns of 'deep refurbishment' where a more substantial fraction of the inventory would be reworked all at once; a deep refurbishment approach would involve "an expensive and complex start-up procedure" and risk the "non-availability of components and materials."[303]

Keeping WE-177 in service for as long as possible was preferable for the government for the principle reason that life extension was far cheaper than acquiring a replacement system. On the basis that a new design would involve a new physics package that would require "twice as much plutonium," the potential expense made one MoD official "shudder at the thought."[304] This was borne out by an MoD estimate in 1984, which predicted that a successor warhead would cost nearly twenty times over ten years more than keeping WE-177 in service (1.20 million vs 20 million 1984 GBP), not included any standoff delivery vehicle which would also likely have to be acquired.[305]

However, indefinite life extension was thought to come at the expense of the weapons reliability. Even with stockpile surveillance, in 1976 it was estimated that multiple internal warhead components would be aged to the extent that they would need replacement between 1983 and

[297] TNA, DEFE19/240, UK Stockpile Reliability in the Absence of Nuclear Experiments, 01/02/1978
[298] Ibid.,
[299] Ibid.,
[300] TNA, DEFE19/240, Surveillance Testing Bomb A/C HE 600/900lb MC, 28/12/1973
[301] TNA, DEFE19/240, UK Stockpile Reliability in the Absence of Nuclear Experiments, 01/02/1978
[302] TNA, DEFE19/240, WE177 - Service Life of Components, 14/11/1974
[303] TNA, DEFE19/240, UK Stockpile Reliability in the Absence of Nuclear Experiments, 01/02/1978
[304] TNA, DEFE19/195, Proposals for WE177 Replacements, 14/02/1977 & TNA, DEFE19/195, WE177 - Replacement Policy, 02/05/1977
[305] TNA, DEFE69/1307, Nth LTC 84 Provision for WE177 and Replacement, 28/08/1984

1986.[306] While a campaign of 'deep refurbishment' was considered periodically in the late 1970s, this was largely rejected on cost grounds as "nearly all the major items" would have to be replaced with modern alternatives rather than original articles.[307] This was an area of concern for the WE-177Bs, where deep refurbishment would involve "stripping down and re-designing and re-making the electronics" if it were to be kept operable.[308] While replacing WE-177 with a modern alternative was the services preferred option, cost imperatives and the limited ability to replace WE-177 with Aldermaston at work on Trident meant that a further life extension to 25 years was countenanced in 1983.[309] In 1984 it was recognised that "degradation [would occur] during this period [and] would be [in] terms of reliability," but "deep refurbishment has been ruled out as a very costly way of maintaining outdated technology."[310] Even so, this was an uneasy position: internal MoD documents from 1986 noted that "as each day goes by, there is an increasing risk that deterioration within the weapon could result in them no longer being able to be stored safely, or… that they would detonate with their planned effect."[311]

TNW Modernisation: Renewing Uninvention

Although the focus of the weapons establishment was on replacing obsolescent technology, the institutional interest that AWRE/AWE had in replacing the WE-177 system can be observed throughout this era, with Macklen in the MoD championing the cause. In February 1977, the momentum for new tactical nuclear weapons systems clearly came from the weapons establishment and the MoD – Macklen and Fakley talked of the need to "sell a new weapon to the Services" and the need to "be consulting more widely than just at AWRE."[312] Other officials noted that "if the UK is to remain in the atomic weapons business, then every opportunity should be taken to get new designs into service."[313] By October 1977, Macklen chaired a meeting "to take sounding on the machinery which would be required to process actions to determine our future UK tactical nuclear

[306] TNA, DEFE11/1768, Nuclear Warhead Research and the Capabilities of AWRE, (n.d.)
[307] TNA, DEFE19/195, UK Nuclear Weapons - Stockpile Production and Upkeep, 04/1977
[308] TNA, DEFE11/793, Future UK Tactical Nuclear Weapons, 07/10/1977
[309] TNA, DEFE69/1307, Report on TNWPSG Meeting, 10/06/1984
[310] Ibid.,
[311] TNA, DEFE25/678, TNWSG Report to COS, 07/07/1986. It has been alleged that 'Trickle production' assisted the degradation of reliability of WE-177s via manufacturing inconsistencies and the accumulation of changes. See Burnell, (2018)
[312] TNA, DEFE19/195, Proposals for WE177 Replacements, 14/02/1977
[313] TNA, DEFE19/195, Comments on Proposals for WE177 Replacements, 14/02/1977

weapon capability."[314] This culminated by 1979 in the formulation of the Naval and Air Staff Target (NAST) 1231; a specification for a successor to WE-177, agreed amongst service chiefs and MoD officials within the ORC(N) committee, but which had yet to be granted political approval.[315]

The advancement of institutional interests based on the need for new nuclear weapons to prevent 'uninvention' and halt progressively declining reliability left some members of the Callaghan administration sceptical about the establishment's arguments. This was not helped by the nuclear testing it would involve contradicting Labour's role in negotiating a comprehensive international test ban treaty.[316] David Owen, a Defence Minister and then Secretary of State for Foreign and Commonwealth Affairs during Wilson and Callaghan's late 1980s administrations believed that "the shelf life argument was a deliberate diversion, the protection of a vested interest by the nuclear testing laboratories."[317]

With no decision over a new TNW in the late 1970s under Labour, the issue re-emerged under Thatcher's new Conservative administration. "A major factor" dictating whether to proceed with NAST 1231 work was whether Aldermaston had the capacity to work on Trident and a secondary project simultaneously; if not, the project would have to wait until the 1990s.[318] The SofS, Francis Pym, briefed the Prime Minister that "the problems at Aldermaston are such that we cannot in any event plan to carry out more than one new nuclear project at a time. Decisions on new theatre weapons must wait."[319] This also ruled out the possibility of a UK built intermediate range ground launched nuclear cruise missile in response to the Soviet SS-20s (in addition to NAST 1231).[320] This was reconfirmed by "the Director [of] AWRE Aldermaston [who] has emphasised that due to resource constraints we shall be capable of producing… warheads only sequentially, and not in parallel."[321] Nonetheless, the RAF were keen to ensure that NAST 1231 did not "take too much of a back seat… [as they believed that] a TNW capability is more valuable than the UK strategic force."[322] Without the ability to immediately initiate a new warhead project, further consultations were made. A policy steering group were tasked by the Chiefs of Staff Committee to consider a successor system in April 1983.[323] While this precipitated a wider discussion over the utility of TNWs,

[314] TNA, DEFE11/793, Future UK Tactical Nuclear Weapons, 07/10/1977
[315] TNA, DEFE25/433, Theatre Nuclear Weapons - NAST 1231, 08/01/1979
[316] Stoddart, (2) (2014), p.25-26
[317] McLean and Beyer, (1987), p.118
[318] TNA, DEFE25/678, UK Theatre Nuclear Weapons Successor System, (n.d.)
[319] TNA, PREM19/14, The Successor to Polaris, 01/11/1979 & Stoddart, (2) (2014), p.209
[320] TNA, PREM19/14, Future of the Strategic Deterrent - MISC 7, 02/11/1979 & Stoddart, (2) (2014), p.209
[321] TNA, DEFE69/1327, Maritime TNW Policy, (n.d.)
[322] TNA, AIR8/2846, Nuclear Matters – Presentation by the CSA, 15/12/1981
[323] TNA, DEFE25/678, UK Theatre Nuclear Weapons Successor System, (n.d.)

similar arguments to those posed by the weapons establishment in the late 1970s resurfaced; a new TNW was needed as it "maintains national nuclear expertise in business" and that WE-177s were reaching obsolescence.[324]

With the production situation at Aldermaston in the 1980s imposing a bottleneck on production and development of TNW, timing became a key issue. It became apparent in 1981 that Trident needed to progress quickly so that a new TNW could be developed before the WE-177s became inoperable. Therefore, officials noted that "we must keep the costs and timing of our strategic nuclear deterrent within bounds so that they do not threaten… the WE 177 replacement programme."[325] With the problems at Aldermaston highlighted in this chapter, this scenario appeared to unfold; the Defence Select Committee was concerned in 1988 that any delays would hinder the WE-177's successor programme to provide a replacement in time.[326] While a definitive decision on replacement was not forthcoming, it was clear that the WE-177 situation was becoming untenable in the early 1990s. Life extension could not be carried out indefinitely. Malcolm Rifkind relayed to the Prime Minister in 1992 that "WE-177 could not be refurbished to modern safety standards without in effect building a new weapon."[327]

With the Trident programme progressing beyond its development phase by the early 1990s, government reconsidered what programme could sustain AWE thereafter. As Thatcher had not made an affirmative decision on TNW modernisation, replacing the WE-177 re-emerged during the Major administration. Once again, AWE's advocates framed the issue of providing a new research agenda to avoid knowledge loss at AWE. In 1991, the cost of not proceeding with a new TNW was estimated to Cabinet at "1000 job losses at AWE" and that "[they] would lack a development task after Trident… The absence of a warhead programme until Trident replacement could call into question the viability of AWE and our role as an independent nuclear power in the long term."[328] The Defence Select committee believed in 1992 that "research… [for] the successor to the WE-177 free-fall bomb is integral to operations at Aldermaston."[329] New work was again being justified as fulfilling the cycle of renewing skills at the Atomic Weapons Establishment.

[324] TNA, DEFE69/1307, 'Strawman' Pros and Cons for Sub-Strategic Nuclear Systems, 28/09/1984
[325] TNA, DEFE25/435, Cost of the Strategic Nuclear Deterrent - ACDS(pol) to PSO/CDS, (n.d.)
[326] Defence Committee, Fourth Report, Session 1988–1989, Statement on the Defence Estimates 1989, Report, Appendices and Minutes of Evidence, 07/06/1989, p.xxvii
[327] TNA, PREM19/4054, The UK's Future Sub-Strategic Nuclear Capability, 06/08/1992
[328] TNA, PREM19/3255, US Arms Control Initiative: Implications for TASM, (n.d.)
[329] Defence Committee, Sixth Report, Session 1992–1993, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 16/06/1993, p.xix

1993: Rejecting Uninvention

With the end of the Cold War in 1991, there appeared little imminent need for new nuclear weapons systems. NATO rapidly began to "significantly reduce… sub-strategic nuclear forces" in line with the Alliance's New Strategic Concept of 1991; the future of TASM as a WE-177 replacement therefore seemed precarious.[330] In addition, the prospects for a Comprehensive Test Ban Treaty being agreed significantly increased under sustained international and NGO pressure from 1991 onwards, especially so after the inauguration of Bill Clinton in 1993.[331] The possible cancellation of the next nuclear weapons development project and imposition of a CTBT posed a dual threat to the weapons establishment, which would once again invoke the possibility of nuclear uninvention.

Although most archival material from 1993 remains classified, officials used the 'uninvention' argument at a cabinet level. For instance, in regards to TASM, the then Head of the Defence and Overseas Secretariat advised the PM's private secretary that "the work programme of AWE (Aldermaston)… is already diminishing fast in content and where it may be hard to keep the team of scientists together without a major new warhead project - which in turn has implications for the long-term viability of a national deterrent."[332] As Trident was "so US dependent, some Americans would also conclude that the UK had taken the first step on the road out of the nuclear business."[333] In addition, Malcolm Rifkind was aware that "access to… American cooperation will depend upon continued significant UK contribution to… [information] exchanges" and this would be "even more important if we face a testless world."[334] In the absence of a new weapons programme for AWE, the few remaining nuclear tests allotted to the UK by the US gained an increased importance as they were necessary to "palliate" Aldermaston to allow for "the best chance of retaining the ability to maintain our stockpile in the long term and preserve the option of replacing Trident.[335] This was because "the continued underwriting of weapons' reliability and safety depends in the long term on the competence and experience of our design teams. Without a test programme it would be difficult in the long run to retain design teams with the necessary expertise."[336] This quote emphasises that until 1993, the predominant view was that nuclear weapons reliability was dependent upon a social process of knowledge transmission.

[330] NATO, (1991)
[331] CTBTO Preparatory Commission, (2012)
[332] TNA, PREM19/4054, TASM, 08/03/1993
[333] Ibid.,
[334] TNA, CAB148/362, The UK's Long-term Sub-Strategic Nuclear Capability, 20/05/1993
[335] TNA, PREM19/4054, OPDN Meeting Minutes, 27/05/1993
[336] TNA, PREM19/4054, Nuclear Testing, 25/09/1992

Despite these attempts to justify both further testing and the TASM project, neither proceeded. SofS Malcolm Rifkind's memorandum to the Overseas Policy and Defence Nuclear sub-Committee in May 1993 noted that this was because "TASM is not affordable" considering the improving security situation.[337] In addition, the need for TASM was further diminished as it was argued that Trident had the additional capability to act as the sub-strategic deterrent too.[338] The end of the Cold War necessitated defence spending reductions, and TASM "was the only discrete, big defence equipment project remaining as a candidate for cuts in the longer term."[339] Therefore, In October 1993, Rifkind publicly announced that the TASM project had been cancelled.[340] The 'uninvention' argument was an insufficiently clear nuclear threat to overcome the mobilised consensus for nuclear defence spending reductions. Nonetheless, Rifkind noted that whatever the TASM decision, "we will also need to safeguard our nuclear design and production capability at AWE for the future."[341] As highlighted, emphasis in this regard had been placed on the final three British nuclear tests, but these were also not forthcoming.

The final three British nuclear tests which had been argued to be necessary were likely halted due to the political impracticality of breaching the American testing moratorium which had been extended in June 1993.[342] Rifkind acknowledged In November 1994 that these developments would "change the focus of some work at AWE, but there will still need to be a challenging programme of research in order to sustain our ability to underwrite the safety and reliability of the warheads we have in service, and to maintain the capability to develop and produce warheads as in the future, circumstances may make this necessary."[343] Without a new weapons programme or the prospects for new tests, combined with the major reorganisation involved in contractorisation, it is unsurprising that fears of nuclear weapons uninvention were expressed by MacKenzie and Spinardi's 1995 article, which would draw from interviews with AWE scientists.[344] However, just as this argument was reaching public consciousness after having been used within government in various forms since at least 1960, a transition was underway due to the CTBT that would place the emphasis of retaining nuclear credibility within impersonalised technical processes, rather than through the ongoing social transmission of knowledge from within an organisation.

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[337] Ibid.,
[338] Ibid.,
[339] Bellamy, (1993)
[340] Lewis, (1996), p.104
[341] TNA, CAB148/362, The UK's Long-term Sub-Strategic Nuclear Capability, 20/05/1993
[342] Lewis, (1996), p.110
[343] Defence Committee, Second Report, Session 1993–1994, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 04/05/1994, p.xxii
[344] MacKenzie and Spinardi, (1995)

Conclusion

Despite initially appearing as a failed attempt to determine the staffing needs of the weapons establishment, the Kings Norton Inquiry cast a long shadow over AWRE. This chapter traced how frustrations over oversight of AWRE led to the establishment's transfer from the UKAEA to the MoD. This was intended to reduce the establishment's autonomy. This restructuring was then linked to staff problems experienced by the establishment in 1978 due to deprioritisation under the MoD. Reorganisation limited Aldermaston's ability to exert its influence; the establishment declined in line with overall economies in defence spending and reductions in civil research at Aldermaston. Furthermore, the transition back to the civil service meant that pay continued to fall in line with inflation as it was tied to civil service pay bands. This meant that the staff complement at AWRE was reduced and often under strength while development and production work for Chevaline and WE-177 proceeded.

The impact of these reductions became evident in 1978 with the plutonium contamination incidents that plunged the establishment into crisis. Poor safety, bad pay and chronic understaffing threatened the continuity of the British nuclear weapons effort. These factors threatened staff recruitment and retention, which in turn would make fissile material handling facilities inoperable. Through a series of pay improvements, triaging staff and recruitment campaigns, the situation was stabilised at the expense of a year's delay in bringing Chevaline into service. Although nuclear weapons uninvention did not occur, a lack of capacity at Aldermaston restricted the Thatcher government's subsequent decisions over whether to pursue British nuclear cruise missiles or new tactical nuclear weapons in the 1980s. Trident acquisition was necessitated through the aging of the Polaris system, but questions were raised over Aldermaston's capability to conduct the work, even if it was simultaneously argued to be needed to guarantee the institution's future.

Although not covered by the existing secondary literature, this chapter inductively tested whether Aldermaston struggled with knowledge management in the 1980s. Even though staffing issues had been an apparent problem with AWRE in the 1970s, the incoming Thatcher government in 1979 only investigated reorganisation. Without change, it is unsurprising civil service pay bands again noticeably threatened the progress of the Trident warhead programme from 1983 onwards. The setting of unrealistic progress objectives and then a wave of industrial disputes conveyed a sense of crisis at the establishment to the government. Only through multiple special pay awards,

recruitment campaigns and improving conditions for AWE's workers was the staffing situation once again ameliorated. Nonetheless, the Thatcher government's frustration with the establishment's perceived inefficiency led towards implementing contractorisation. The similarity in pre-existing processes and subsequent justifications for the transitions to contractorisation and the UKAEA in the 1950s is striking and highlights the establishment's cyclical trajectory.

Despite any organisational issues, the weapons establishment had been proactive in attempting to retain necessary skills and expertise. Based on the need for skills portrayed in the Kings Norton inquiry, AWRE established 'trickle' production to maintain skills on a more continuous and sustainable basis. In addition, the 'uninvention' argument was used to acquire laser simulation facilities in 1976 and continued to justify the expansion of a wider experiment and simulation programme that complimented nuclear weapons testing.

Nonetheless, by 1993, the issue of how to sustain AWE into the future returned to the fore as the developmental work on Trident reached completion. While officials put the 'uninvention' case for TASM to government, the end of the Cold War ensured the lobbying attempt failed. Similarly, the warnings made over the importance of continuing nuclear testing went unfulfilled as CTBT talks proceeded. This represented a final rejection of retaining nuclear weapons knowledge at AWE through ongoing weapons programmes and tests. AWE substituted social knowledge gained through practice for other technical means in a substantial change to the paradigm as practiced between 1947 and 1993.

Chapter 7: Contemporary Trends, Conclusions and Implications

Contemporary Trends

In 1993 Spinardi predicted the possible "death" of the British nuclear deterrent through the combination of private management, the end of live nuclear testing and the cancellation of TASM.[1] Spinardi additionally claimed that whether "morale and expertise will wither away… may be the ultimate test (for Aldermaston) of the 'Zuckerman thesis.'"[2] This proved a momentous year for AWE and many of these sentiments were conveyed to the Overseas Policy and Defence Nuclear sub-Committee. Nonetheless, AWE's work continues to the present. So far, British nuclear weapons have not been uninvented. This raises several questions: How has Aldermaston sustained itself? What changed from 1993 onwards, and what trends have remained the same?

The main discontinuity was a shift in heterogeneous engineering; rather than 'selling' skill, after 1993, AWE placed emphasis on establishing a scientific process for maintaining nuclear credibility. This in turn meant that rather than retaining personally embodied skills, through upholding 'momentum' with the continuity of work and a focus on recruitment and retention of staff, the process of guaranteeing nuclear weapons credibility became one wherein the emphasis was placed on a technical process of physics simulations rather than upon peoples' judgement of what constituted a viable physics package based on experience. This was later observed by MacKenzie and Spinardi, who witnessed efforts in the US and UK to 'black box' as much formally tacit nuclear weapons expertise into an explicit knowledge based scientific process as possible.[3] The importance placed upon this transition by AWE, MoD and the Cabinet Office is evident in UK Cabinet documents from 1993, where there was an immediate "need to invest heavily in… alternative means" of verifying nuclear weapons credibility for both potential future designs and aging stockpiled warheads.[4] This meant placing a great emphasis on "developing the AGEX [(Above Ground Experiments)] work."[5]

[1] Spinardi, (1993)
[2] Spinardi, (1997), p.575
[3] MacKenzie and Spinardi, (1995), p.79
[4] TNA, PREM19/4054, Nuclear Testing, 25/09/1992 & TNA, CAB148/362, The UK's Nuclear Testing Programme, 20/05/1993
[5] Ware, (1995), p.14 & Defence Committee, Second Report, Session 1993–1994, The Progress of the Trident Programme, Report, Appendices and Minutes of Evidence, 04/05/1994, p.xxiii

From 1993 onwards, the function of work at Aldermaston has been to develop a "new scientific methodology…[which] without further nuclear tests, [is] aimed at underwriting the safety and performance of the ageing Trident stockpile with continued high confidence.[6] As this would have to "be done without the support and knowledge of the staff who actually designed, tested and put into service the British Trident warhead," this capability would be based on non-nuclear hydrodynamic experiments, computational simulations and plasma physics research.[7] This necessitated immediate investment into new computer simulation capabilities with the purchase of both CRAY and IBM supercomputers, which became operational in 1996 and 1998 respectively.[8] As all future simulations would be based on previously acquired data and increasingly without the experience of staff who had conducted live testing, an effort was made in conjunction with the United States to archive and make accessible as much historic nuclear weapons relevant data as possible.[9]

This process continued under New Labour, who despite electing to relinquish the remaining WE-177 systems in inventory in 1998, sought to retain a "robust capability at the Atomic Weapons Establishment to underwrite the safety and reliability of our nuclear warheads, without recourse to nuclear testing."[10] In addition, "a minimum capability to design and produce a successor to Trident should this prove necessary" was also to be retained.[11] In "discharging the undertaking… [given] in the Strategic Defence Review," a significant initiative undertaken by Labour was a £100 million joint investment into the US National Ignition Facility.[12] This signposted how investments in physical infrastructure were replacing the prior emphasis on retaining tacit knowledge skills.

Despite these pledges, by "the late 1990s…the AWE budget and workforce…[was down] to a level of about 50% of the levels of the early 1980s."[13] The proportion of government research and development spending at Aldermaston was in steady decline during the 1990s.[14] According to documents obtained by Burt, the degradation of the capability of AWE led "the MoD's Chief Scientific Advisor [O'Nions]… [to recommend] an 'urgent and substantial increase to the UK's warhead capability'" in 2002.[15] In turn, the MoD's CSA study of Aldermaston's capabilities led to the

[6] O'Nions et al., (2002)
[7] Ibid.,
[8] Hawkings, (2000), p.102
[9] Lawrence Livermore National Laboratory, (1995), p.211
[10] HM Government, (1998), p.117-118
[11] Ibid., p.118
[12] George Robertson, HC Written Answers 07 May 1999 vol. 334 cc341 & Butler and Bromley, (2001), p.18
[13] Price, (2006), p.112-3: Price states 3600 were employed by AWE in 2003
[14] Milne, (1998), p.185
[15] Nuclear Information Service, (1)(2016), p.15

initiation of the Nuclear Warhead Capability Sustainment Programme (NWCSP), which was endorsed by a Cabinet committee in 2004 and announced to the public in 2005.[16] In a written statement, the then SofS John Reid announced that "it is necessary to invest in the facilities at AWE which will provide assurance that the existing Trident warhead stockpile is reliable and safe."[17] In line with this objective, the NWCSP (which continues to the present, with a predicted end in 2025) has seen a significant increase in capital spending at Aldermaston to build new physical infrastructure.[18]

Nonetheless, the MoD were both concerned over the fragility of technical knowledge at AWE in 2004 and the possibility of nuclear uninvention. Kevin Tebbit, a former Permanent under Secretary of State for the MoD provided justification for the NWCSP in 2007 and reflected on the history of the British nuclear weapons programme when he stated that:

"Often political decision-makers are insufficiently sensitive to the reality that unless you are prepared to invest in sustaining technological and scientific capacity throughout a period, the option to go for a new system may no longer be there when politicians finally decide that they want it.

One of the really important bits of the history is the sustainment of the scientific and engineering base that has been needed throughout this period. I mention this because it nearly hit us very recently before the Government took the decision to invest in warhead sustainment in 2004. That background may not feature in the political history… but actually has always been a very critical aspect. I think the first thing we should say is there were times when this was very fragile, and we all owe a huge debt to the people at AWE and other places that kept it going in the quiet times."[19]

As noted by Price, the initiation of the NWCSP "did not represent any change of policy" for Labour, and has since continued to the present under multiple governments.[20] The programme incorporated the AWE Site Development Context Plan, which has continued to see major capital spending diverted to AWE, which enjoyed in 2015 "five times the level of spending in the year 2000."[21] The MoD announced in 2012 that they would be "investing £1bn a year in facilities at the Atomic Weapons Establishment… until 2020."[22] This investment has manifested in the construction of a range of new facilities and infrastructure. Major works include the new Orion laser facility, that

[16] FOI document: Ministry of Defence, "MoD Screening Form (MoD Form Norm 1923)", n.d. Although Burt contends that it had been initiated in 2002, with £100 million being spent on the programme between 2002 and its announcement in July 2005. Burt, (2011), p.15
[17] Lord Drayson, HL Written Answers, 19 July 2005 vol. 436 ccWS71
[18] Cullen, (2019), p.12
[19] The British Academy, (2007)
[20] Price, (2006), p.112
[21] Youngman, (2017), p.2 & AWE, (2005), p.2
[22] Mills, (2014), p.7

became operational in 2013, Circinus, a new high explosives fabrication facility and ongoing work on the Mensa warhead assembly facility.[23] Supercomputer facilities used for simulations have been continually upgraded with new hardware installed in 2002, 2006, 2010, 2014 and 2015.[24] The timely delivery of this new infrastructure within the NWCSP is critical to the completion of the improved Mk4A warhead "in line with…the programme imperatives" and for the initial planning for a Trident "Replacement Warhead programme."[25]

If the future of the British nuclear programme increasingly rests on the utilisation of advanced infrastructure rather than the transferred skills of designers with experience, then the ability to complete capital investment programmes takes on a new importance. Unfortunately, from AWE's perspective, many of these projects have experienced delays and cost overruns such as Project Hydrus. Despite having to write off nearly £120 million, the construction of a new hydrodynamics facility was cancelled in favour of sharing a joint facility (Project Teutates) with France.[26] Similarly, work on the Pegasus replacement uranium handling facilities at AWE are "currently suspended" for unknown reasons and it is uncertain if the project will ever resume.[27] A recent NAO report also revealed that "a lack of skills" in the Defence Nuclear Enterprise was contributing to the risk of delay or non-delivery of infrastructure by its inability to challenge contractor's "over-specified designs."[28] This apparently significantly "contributed to cost increases and delays" at the Mensa warhead assembly facility.[29] Mensa was reported as running "six years late, with a 146% (£1.1 billion) cost increase, arising in part because the Department started to build with only 10–20% of the design complete."[30] If the continuity of the British nuclear weapons programme is reliant on new infrastructure that generates new explicit knowledge relevant to stockpile maintenance, then the record of its delivery is concerning.

Even if the emphasis of maintaining Britain's nuclear weapons credibility has transitioned from people to an impersonal scientific process, this does not mean a similar uninvention argument cannot be made. While primary sources are lacking, The MoD CSA's argument for the NWCSP in 2002 appears to invoke potential uninvention, thereby providing justification for new infrastructure

[23] The full range of facilities (including those constructed as party of the NWCSP, under construction or waiting approval) are listed in Nuclear Information Service, (1)(2016), p.16 and Stuart Andrew, HC Written Answers, 06 December 2018, c.198373
[24] Nuclear Information Service, (1)(2016), p.18
[25] HM Government, (2018)
[26] Burt, (2011), p.16 & Michael Fallon, HC Written Answers, 17 December 2015, c19414
[27] Cullen, (2019), p.20
[28] National Audit Office, (2020), p.31
[29] Ibid., p.31
[30] Committee of Public Accounts, Sixty-First Report, Session 2017–2019, Ministry of Defence: Nuclear Programme, 10/09/2018, p.6

spending.[31] This poses the same problem as witnessed in previous chapters – how does the rest of government determine the minimum requirement of AWE to remain sustainably functional? In an attempt to determine the establishment's requirements, the SoS and MoD CSA are advised by the Nuclear Research Advisory Council, which was founded in 1996 and is "responsible for reviewing… the [AWE] nuclear warhead research and capability maintenance programme."[32] Given their institutional role in determining AWE's AGEX and international collaboration requirements, their apparent solution to perceived deficiencies has been to invest in facilities intended to 'black box' the previously socially based process of nuclear weapons design.[33] However, this course of action is reliant on the delivery of these new projects, which has apparently proven challenging for the Defence Nuclear Enterprise.

Continuing Relevance of Tacit Knowledge

Sims and McNamara observed that within US labs, the belief in the importance of tacit knowledge (still expressed in terms of skill) transitioned from being held by experienced individuals to being held on an institutional level, dependent on ongoing transactions between practitioners.[34] A similar process of epistemological reorientation can be seen at AWE; communications from Aldermaston and government clearly identify the belief for the need to sustain nuclear weapons relevant skills within AWE as a centre of practice and collaboration, rather than as a site that employed skilled individuals.[35] For instance, after identifying the need to invest in physical infrastructure at AWE 2002, it was equally acknowledged that staffing levels would have to be increased from historic lows.[36] This was also in recognition of the fact that the staff who had conducted "the Chevaline and Trident programmes [were] near the end of their careers."[37] Rather than emphasising the continuity of transferred skills, these new staff would be "of the highest intellectual calibre" to conduct AWE's new science based approach.[38] A 2004 MoD document made an even more optimistic case for the post CTBT programme, suggesting that the NWCSP could "maintain and replenish as necessary AWE's key skills and intellectual capability."[39] Similarly, the

[31] Nuclear Information Service, (1)(2016), p.15
[32] Knight, (2014), p.7
[33] Ibid., p.7
[34] McNamara, (2001), p.4 & Sims, (2007)
[35] HM Government, (2015), p.4 & p.24 & Hawkings, (2000), p.109 & Sims, (2007)
[36] Ritchie, (2009), p.17 & Butler and Bromley, (2001), p.17
[37] HM Government, (2006)
[38] O'Nions et al., (2002)
[39] FOI document: Ministry of Defence, "Investment at AWE – Handling Strategy", 21/06/2004

NAO expressed the MoD's aim to "develop" rather than retain "an appropriately skilled workforce and improve infrastructure by the mid-2020s" in 2018.[40] This indicates the belief that the skills needed to operate the establishment can be regenerated internally through a collective process without dependency on an inherited knowledge base generated through weapons design validated via occasional testing.

AWE demonstrates its view that it can develop and retain tacit knowledge through knowledge transactions by the increased importance placed upon peer review and collaboration outside of the establishment. In terms of international collaboration, Cabinet documents expressed the need in 1994 to establish as much peer review of nuclear weapons stockpile science as possible between the UK and US and even potentially France.[41] This initially manifested with a reformation of the UK/US JOWOGs in 1995 to allow for better information exchange.[42] More recently, the 2010 UK-France Defence Co-operation Treaty, which was later expanded upon in a joint 2014 Declaration on Security and Defence, led Harries to speculate that the exchange of classified information and the joint Teutates facility will allow the partners to "share and converge in working practices, assumptions and practical knowledge, similar to the 'peer review' dynamic between the United Kingdom and United States."[43] According to O'Nions et al., "performance assurance" of British warheads is further enhanced through "working ever more closely with British academic and industrial communities, and benefiting mutually through international collaboration."[44] One example is how AWE allows academics access to the ORION laser facilities for civil experiments.[45] Inexplicable tacit knowledge 'special' skills appear no longer the basis of nuclear weapons development, but it now appears a collaborative approach is now needed to support AWE.

Although the above programmes suggest an entirely new model for knowledge retention at the establishment, some modes of practice at AWE are more in keeping with their pre-1993 methodologies. For instance, as with WE-177, it appears that trickle production for Trident warheads continues to ensure production and fabrication skills are routinely practiced.[46] In addition, while full-scale live nuclear testing has been halted, the UK has conducted joint sub-critical nuclear experiments with the US in 2002 and 2006 and continues to support the ongoing US sub-critical

[40] Comptroller and Auditor General, (2018), p.20
[41] TNA, CAB148/369, UK Nuclear Warhead Capability and Prospects for Cooperation with France and the US, 24/01/1994
[42] Sandoval, (2018), p.12
[43] Harries, (2012), p.14 & HM Government, (2014)
[44] O'Nions et al., (2002)
[45] AWE, (2018)(1)
[46] Milne et al., (2002), p.14

testing programme.[47] The 2006 test in particular raised questions as to whether the UK was developing an equivalent of the US Reliable Replacement Warhead (called the High Surety Warhead).[48] The MoD subsequently described any work conducted for the High Surety Warhead as only an "'academic study' intended to 'show that AWE had the skills and knowledge to produce a replacement warhead to Trident if the Government made such a decision in the future.'"[49] Consistent with this theme, the AWE Educational Collection displays the results of a similar exercise to develop a nuclear cruise missile (named Operation Herdick), with the missile component reportedly tested in the US.[50]

As with AWRE's need for a new programme in the 1960s necessitating the Polaris Improvement Programme, the extent to which knowledge management and AWE's capability is dictating current nuclear policy is also relevant; the 2013 Trident Alternatives Review suggested that while a replacement warhead for Trident could be delivered in "17 years" as "the missile and its environmental data is well-known."[51] In comparison, developing a warhead for a cruise missile would take a predicted "timescale of 24 years," which "is judged to be longer than the Vanguard-class SSBN submarines can safely be operated."[52] This could be alleviated by an "accelerated warhead programme… but it would come at high risk and would need to be driven as a UK national imperative." As the skills and capacity of Aldermaston dictate the timeframe for warhead development, and producing Trident alternatives were predicted to take longer than Vanguard's expected lifespan, this suggests that Britain's nuclear deterrent is path dependant, with retaining Trident as now the only viable option.[53]

Ongoing Organisational Changes

A consistent trend identified by this thesis has been AWE's ongoing organisational changes. Reorganisations were intended by government to balance the establishment's autonomy against the costly effects of the information asymmetries in the principal-agent relationship with the establishment. It was initially hoped that contractorisation would "provide a new and sharp tool" for maintaining "capability… at the lowest practicable cost."[54] However, such an arrangement depended

[47] NNSA, (2006) & NNSA, (2015), p.8
[48] Lewis, (2007)
[49] Nuclear Information Service, (1)(2016), p.29
[50] Witnessed and conveyed to the author on an AWE site visit 08/02/2018
[51] HM Government, (2013), p.6
[52] Ibid., p.6
[53] Ibid., p.6, See also Chalmers, (2013)
[54] TNA, CAB148/369, UK Nuclear Warhead Capability and Prospects for Cooperation with France and the US, 24/01/1994

on managing the contractor effectively. The Hunting-BRAE arrangement was quickly transitioned in 1995 from a "cost-plus contracts to Target Cost Incentivised Fee" model to incentivise economic efficiency in the face of possible loss from a system where profit was guaranteed regardless of delays in matching targets.[55] Nonetheless, following two safety related prosecutions from a newly empowered Health and Safety Executive, Hunting-BRAE's contract was not renewed in 1999.[56] Despite the Thatcher government's initial hopes, this first foray into contractorisation had therefore failed to provide a stable basis for managing Britain's nuclear weapons establishment.

Management passed onto a new consortium, AWE Management Ltd., composing of Lockheed Martin, BNFL and Serco.[57] Despite this change, safety problems remain. The site has experienced numerous fire and safety related incidents with varying degrees of seriousness; a 2010 fire at the explosives manufacturing facility resulted in one worker injured, as did an electrical fault accident in 2017.[58] Operations in the A45 uranium handling facility were temporarily halted due to the discovery of corrosion of structural steel in 2013.[59] The replacement facilities, named Project Pegasus, have faced "spiralling" costs and work was placed "on hold" in 2015 and as of 2019, "no clarity on when work will restart" has been provided.[60] Similarly, live warhead work was temporarily halted in 2008 at Burghfield due to age related defects discovered in warhead disassembly bays during safety inspections and its replacement is still overdue due to 'over-specification,' in turn stemming from poor communication between contractors, regulators and the MoD.[61] AWE also faces the problem of preventing leaks from the accumulation of high activity radioactive waste that has been stored on site since 1983, when disposal at sea was halted.[62] Although it is planned to eventually relocate this material to the planned Geological Disposal Facility, AWE has since applied to increase its permitted levels of radioactive discharge.[63] Due to a combination of the above safety considerations, AWE has remained on the Office of Nuclear Regulation's "Enhanced level of regulatory attention" status since 2013.[64]

Although it was reportedly considered bringing the management of AWE back "in-house," the MoD decided to renew AWE Management Ltd.'s contract in 2016, but insisted upon

[55] Lawrence Livermore National Laboratory, (1995), p.35
[56] Tromans, (2010), p.25
[57] Global Security, (2019). BNFL would later sell their share in 2008.
[58] AWE, (2010), Morton, (2012) & Nuclear Information Service, (1)(2018)
[59] Edwards, (2013)
[60] Leftly, (2014) & Collingridge, (2019)
[61] Nuclear Information Service, (2)(2018) & National Audit Office, (2020), p.8 & p.32
[62] Cullen, (2017). For information of a leak of tritium in 2013, see BBC, (2013)
[63] AWE, (2018)(2)
[64] Nuclear Information Service, (2019)

"restructured and new senior management appointments."[65] Construction firm Costain has replaced Jacobs as the main contractor for Project Mensa.[66] While some change is evident, Burt has repeatedly criticised the government's ability to provide "supervision or oversight" over AWE's for-profit management, and the National Audit Office recently recognised in reference to work at AWE that "monopoly suppliers in a specialised sector make it difficult to incentivise contractors and drive value for money."[67] One barrier to reviewing the progress at AWE is that NWCSP efforts are exempt from annual reporting under the Defence Major Projects scheme.[68] An effort to improve oversight was implemented in April 2016 with the creation of the Defence Nuclear Organisation, which now "manages warhead programme and contracts directly" with AWE Management Ltd.[69] Whether this will improve the delivery of the infrastructure programme is yet to be seen. As the NWCSP relies on new infrastructure, ensuring its timely delivery will continue to be a priority, and regulating the management of Aldermaston remains a challenge for present governments due to a reliance on a "monopolistic supplier environment."[70] One commentator has recently warned of accidental nuclear uninvention, as unless management issues are addressed, he believes that AWE is already starting to "implode."[71]

Conclusions

Through the analysis of archival documents, this thesis has traced how the British nuclear weapons establishment developed a sense of its own requirements for skills and knowledge to remain viable. While often expressed in terms of 'skills' or 'qualified staff' rather than in tacit knowledge terms, the establishment gradually developed an analogous sense of modern knowledge management. As demonstrated in each chapter, this manifested in a repeating cycle with the reoccurrence of several interlinked intervening mechanisms where concerns over knowledge management led to heterogeneous engineering, followed by a government response. AWRE offered the development of physical artefacts in attempts to solve the underlying social problem of internal knowledge transmission. Although this cycle occurred repeatedly, the outcome of each attempt

[65] Leftly, (2014) & Nuclear Information Service, (2)(2016)
[66] Office for Nuclear Regulation, (2018)
[67] Comptroller and Auditor General, (2018), p.57
[68] Nuclear Information Service, (2015)
[69] Comptroller and Auditor General, (2018), p.16
[70] National Audit Office, (2020), p.37
[71] Collingridge, (2019). See also Plant, (2020) for policy suggestions to remedy infrastructure delivery problems at AWE by increasing the role of the Defence Select Committee by establishment of a new subcommittee and providing greater resources to the Nuclear Research Advisory Council.

varied due to the contemporary principal-agent relationship between Whitehall and AWRE and the principal's commitment and consensus over a course of nuclear weapons policy. After each cycle, the government often attempted to rectify the establishment's concerns via reorganisation.

Even if only rarely decisive, this process formed an alternate mechanism of influence over the British government's nuclear weapons policy autonomous of strategic considerations of nuclear weapons requirements. As a result, explaining this process achieves the aims of this thesis in exploring how nuclear weapons establishments respond to knowledge management challenges, how they exert institutional interest and how this has influenced British nuclear weapons history. Given that this reoccurring process stems from inherent knowledge management issues relating to nuclear weapons, one would expect this process to have occurred within other nuclear weapons states with comparable institutions and therefore act as a driver of vertical proliferation within certain bounds.

Within the British nuclear weapons establishment, the realisation of the need to effectively manage knowledge quickly became evident. The underlying need for HER to retain qualified staff was emphasised early on with its experience in competing for manpower, particularly with the ARD. HER's rapid expansion and its pervasive aura of secrecy compounded staffing issues. Even by the end of the fission programme, transmission of an analogous conception of tacit knowledge was seen as necessary to continue the nuclear programme; Penney noted in 1952 that unless continuous recruitment and retention of staff could be maintained, then the establishment would become "sterile."[72] The self-identification of individuals with nuclear weapons relevant tacit knowledge was evident from 1954, where particular staff identified themselves as "weaponeers" with specialised nuclear skills that would not be easily replicated or transferred.[73] The loss of 'skilled' staff was an ongoing threat to the nuclear programme between 1959 and 1962, 1966-1968 and cited repeatedly in justifications for the HELEN laser system, Trident and TASM. AWRE's practice of 'trickle' production from 1970 demonstrated its belief in the need to preserve skills through practice, where nuclear weapons work was conducted purely to retain and transmit knowledge.

This is not to say that AWRE's conception of tacit knowledge was static. As highlighted in the framework, what constitutes tacit knowledge can encompass ineffable physical skill to information that can be painstakingly codified. For AWRE, both the conception of who held 'special skills,' what they were and how they could be propagated changed over time. Initially, references to skills shortages during the HER period were most acute for hydrodynamics.[74] As MacKenzie and Spinardi

[72] TNA, ES1/83, CSHER to Mr. Wilkinson, 25/08/1952
[73] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[74] Gowing, (2) (1974), p.72-74

have detailed in the American experience, although hydrodynamics has mathematical models and was increasingly computerised as time progressed, judgements were largely made via personal "intuition."[75] This explains why disagreements over the split of HER and the ARD were so intense as it meant inheriting workers with this sense of judgement.[76] As AWRE progressed with the thermonuclear programme, workers with several of these specialist skillsets began to identify as 'weaponeers.' As this was during a morale crisis, it was clear that this was partially a rhetorical position to extract better conditions (and hence why it was disputed by other UKAEA workers), but sufficiently convincing to Penney and the rest of the AEX to devote considerable attention to alleviating their concerns.[77]

AWRE's advocates developed knowledge management-based arguments favouring institutional interests from 1954 onwards and especially under the threat of reductions after the Grapple tests. By 1962 this had matured into an institutional belief that AWRE associated officials would repeat throughout the decade; it would encompass notions of both personal somatic and establishment wide collective knowledge. AWRE, MoD and UKAEA officials stressed that the retention of both of these forms of knowledge was necessary for overcoming future research and maintenance issues. Although this formulation would remain recognisable until 1993 when the halting of live tests introduced a more transactional view of knowledge, a change in approach is apparent after the Kings Norton Inquiry. As highlighted in Chapter 6, AWRE used contemporary notions of tacit knowledge in the late 1960s with the same purpose as Polanyi's original conception: to prevent "governmental incursions into and elimination of practitioners' professional power of judgment."[78] However after the inquiry, as Schmidt identifies in the general history of use of tacit knowledge as a concept, the need to preserve 'skills' was increasingly viewed as "a problem to be overcome" rather than just an intractable barrier preventing inquiry.[79] Attempts to overcome this barrier with an analogous sense of modern knowledge management included the adoption of 'trickle' production and early attempts to 'black box' hydrodynamics via simulations. This coincided with a second trend identified by Schmidt; technicians rather than just scientists were increasingly viewed as holding tacit knowledge.[80] Concerns over the loss of technical rather than scientific tacit knowledge were amplified by the loss of workers due to the events surrounding the Pochin inquiry and AWRE's more general shift in focus from theoretical research towards preserving manufacturing

[75] MacKenzie and Spinardi, (1995), p.56
[76] Gowing, (2) (1974), p.451
[77] TNA, AB41/588, Atomic Energy Executive – Conditions of Transfer of Staff, 13/01/1955
[78] Schmidt, (2012), p.194
[79] Ibid., p.198
[80] Ibid., p.205

techniques. Although unqualified to pass judgement on the levels and types of nuclear weapons related tacit knowledge needed to be maintained, this thesis fully concurs with Lynch's general assessment that "as long as relevant non-professionals assume that the tacit knowledge is legitimate, they must trust what the experts say because they have no basis for evaluating it themselves."[81] Whatever the favoured contemporary notion of tacit knowledge involved, claims to this authority and resistance to the oversight of external parties to judge the levels of skills involved remained consistent throughout the establishment's history. It is therefore unsurprising that conceptions of tacit knowledge can aggravate principal-agent issues, either in the nuclear field or beyond.

As such, while notions of analogous senses of tacit knowledge may have shifted over time with AWRE's differing engineering challenges, the perceived need to preserve or attempt to encode them was consistent. Penney first highlighted this concern in 1952 with worries over the establishment's potential sterility. This was in part due to the process of recruitment and retention of staff always being challenging; Cherwell had noted in 1953 that work within the UK nuclear weapons programme often compared unfavourably with other defence research or civil work due to hazardous conditions, relatively poor pay and burdensome secrecy.[82] The relative attraction of working at Aldermaston was also effected by the intermittent 'threat' of nuclear disarmament, a lack of a main research effort or deprioritisation from government. The combination of the above factors produced intermittent crises of morale, noted in all the eras examined by this thesis. This in turn threatened recruitment and retention. In the immediate prelude to both the thermonuclear programme and Trident, a morale crisis immediately preceded the need to significantly expand the establishment to conduct the new programme. A severe drop in retention and recruitment from poor morale posed an existential threat to the establishment, both in terms of the immediate needs of the establishment to conduct work and to transfer tacit knowledge to the next generation of staff.

With the immediate need to offset morale problems, considerable effort was made by the nuclear weapon establishment's management to offer a range of incentives. As evidenced in the first two case study chapters, both Penney and Cook devoted considerable attention to implementing measures to retain staff. These included better pay when it could be negotiated, improving working conditions and building accommodation and facilities in the local area. To gain staff, recruitment campaigns were conducted nationwide, leveraging talent from the armed services and UKAEA when possible. While any longstanding organisation needs to continually refresh its workforce, consistent

[81] Lynch, (2013), p.67-68
[82] TNA, AB16/1230, Lord Cherwell to Duncan Sandys, 15/09/1953

recruitment was especially important as Aldermaston's management emphasised the need to transmit knowledge from generation to generation. Therefore, the inability to recruit and retain staff appeared to pose both immediate problems to production but also a long-term threat to the establishment. This was demonstrated with the concerns over the organisation of the HER project in 1952, the problems with 'need-to-know' secrecy and education in 1958 and most explicitly with concerns over the age 'bulge' in the late 1980s.

As a result of the need to transmit and retain tacit knowledge through practice, AWRE management and MoD officials consistently expressed their belief from 1954 onwards in the need for research momentum to be maintained at a sufficient level so that skills could be practiced and passed on. The main attempt at this was the provision of diversification work, which was meant to provide the "long term" solution to Aldermaston's staffing problem.[83] Providing additional work was intended to mean that Aldermaston could better guarantee a more reliable supply of work to its staff in-between weapons development projects, thereby making AWRE a more attractive career prospect. The immediate need to deliver diversified work was lessened by the thermonuclear programme between 1954 and 1958 and although sufficient non-nuclear weapons work was promised by successive Conservative and Labour governments, diversification never provided the establishment with enough of a basis to believe itself secure. Military nuclear work was either denied to Aldermaston in the case of naval reactors for fear of delays or there was insufficient demand, such as with 'package' reactors for the army. AWRE proved too expensive as a civil research institute due to the onsite security making it uneconomical compared to Harwell in the 1960s. This work had been intended to provide a sustainable resolution to knowledge management issues within Aldermaston, but itself had proven too expensive in the face of periodic economic crises.

With Aldermaston's management consistently viewing its own skills base as insecure and fragile, the continuity of knowledge transmission could only be guaranteed if sufficient nuclear weapons work was provided. This was made acute by the rapid expansion of AWRE to fulfil the Grapple programme, wherein Cook and Penney instituted a range of measures that saw Aldermaston's staffing figures expand from 3900 in 1954 to nearly 9000 by 1960.[84] The cessation of the Grapple tests in 1958 and the adoption of American warhead designs, combined with Macmillan's Future Policy abandoning the role envisaged for nuclear weapons in the Sandys' 1957 White Paper instigated a morale crisis at AWRE wherein management were concerned over the

[83] TNA, AB41/588, Top Secret Annex to AEX 5th Meeting, 12/03/1955
[84] TNA, AB16/2303, Comparison of Actual with Estimated Strengths, (n.d.)

establishment's future. It was therefore unsurprising that between 1960 and 1962, Levin and Makins openly warned of the possibility that the nuclear weapons programme would not be able to continue unless provided further research work.

This period marked a pivotal moment in AWRE's history. As Spinardi notes "for most of its history, Aldermaston has had its hands full meeting existing weapons 'requirements.'"[85] This was certainly true between 1947 and 1959, but after 1960, the establishment faced reduction from its peak manpower levels. Premised on the need to sustain the future of the weapons establishment, Makins called for an 'Advanced Warhead Development Programme' to resolve social and managerial concerns, regardless of the need for the specific artefact.[86] A process of heterogeneous engineering was therefore occurring as weapons work was being forwarded on the premise of retaining skill. AWRE's demand for further work was nullified after the cancellation of Skybolt and the acquisition of Polaris. Nonetheless, the need had re-emerged by 1966. As demonstrated by William Cook's approach to the Chiefs of Staff, the initiation of a hardening programme was again premised on sustaining Aldermaston. Officials again cited this argument at the end of Chevaline development, as further justification for Trident and in attempts to defer cancellation of TASM. Citation of potential skill loss leading to Britain's nuclear arsenal was therefore cyclical, matching with the "fluctuations in the flow of work… [with its] peaks and troughs" – a dynamic recognised by Francis Pym's review of Aldermaston's management.[87]

In repudiation of the 'Zuckerman thesis,' invoking the possibility of nuclear uninvention to justify further nuclear weapons did not mean that the weapons establishment consistently acquired additional programmes. Only in a few of Britain's major nuclear decisions did the nuclear establishment play an influential role. This thesis has found little evidence that parochial or institutional interest played any significant part in Britain's initial nuclear weapons proliferation decision, the thermonuclear programme, the formation of the strategy behind the 1957 Defence White Paper, anglicisation of American designs or the acquisition of Trident. In all the above, it appears that politicians were firmly in control of the principal-agent relationship between themselves and the establishment. Indeed, in both the case of adopting American designs in the late 1950s and avoiding uniqueness with Trident, Aldermaston was deprived of the additional work that would have been required with indigenous programmes. In the cases of TASM, despite clear warnings of the needs for further developmental work, the end of the Cold War ensured that the establishment's concerns were overruled. Nonetheless, pressure from AWRE was able to acquire

[85] Spinardi, (1997), p.572-3
[86] TNA, CAB134/2239, NRDC Minutes, 17/06/1962
[87] TNA, PREM19/2200, The Future of AWRE: Advantages and Disadvantages of Change, (n.d.)

diversification research, initially used to justify the Polaris Improvement Programme and then acquire the HELEN laser facilities in the 1970s.

Given the variability in the success of the uninvention argument in obtaining further work, understanding the political context is necessary. As highlighted in Chapter 5 with the difference in outcomes between the Wilson and Macmillan governments, this differing success of the 'uninvention' argument can be attributed to varying approaches to 'delegation' versus 'mobilisation' under Saunders' model for the domestic politics of nuclear choices.[88] When confronted with relative threat clarity such as for HER, the thermonuclear programme or replacing Polaris with Trident due to uniqueness, governments effectively mobilised resources in favour of the weapons establishment. Under such conditions, AWRE expanded; although the uninvention argument developed, pressing the case to government was unnecessary. However, when political will was mobilised towards reducing defence spending such as Heath's or Macmillan's second administration, these cabinets were willing to ignore 'uninvention' warnings, regardless of AWRE's concerns.

When political consensus on nuclear decisions was most lacking or when international arms control threatened the longevity of the programme, the 'uninvention' argument appears to have been most potent. Under Saunders' framework, these conditions increased 'uninvention's' "threat clarity."[89] The acquisition of diversification work was instigated in part due to the belief that international arms control for nuclear weapons may have been imminent. The Wilson government's drive for diversification under the 'white heat of technology' and then Polaris Improvement were ways of providing work while retaining the commitment not to develop a new generation of nuclear weapons. The acquisition of the HELEN laser and the transition to a scientific based stockpile stewardship approach after 1993 was in response to concerns over the CTBT.

The success of each attempt to advance nuclear weapons work premised on knowledge management grounds also depended on the relative political influence the weapons establishment had with government. This fluctuated depending upon the individuals involved. The close relationships between figures such as William Penney, William Cook and Victor Macklen to senior government officials appear to have been influential in overcoming reluctant departments, especially the Treasury. While this may have been personality driven, there was also a structural component. The secrecy and urgency of the initial fission and then fusion programme had thrust Cook and Penny into regular contact with the Cabinet and successive Prime Ministers. Contemporaries noted this variable when observing how nuclear policy was initially confined to an

[88] Saunders, (2019), p.175
[89] Ibid., p.184

"exceptionally limited circle" of individuals.[90] The stature of directors of Aldermaston appears to have progressively declined, especially after 1973 when the MoD subordinated AWRE. Whereas Penney directly advised the government on arms control negotiations, AWRE's subsequent directors' communications were channelled through the MoD and the chairman of the UKAEA. The consolidation of the Ministry of Defence in 1964 also appears to have temporarily bolstered Aldermaston's influence when Cook became Assistant Chief Scientific Advisor (Projects). Macklen inherited this role and continued to champion Aldermaston's cause within the MoD until 1979, and thereafter CERN further diluted AWRE's influence. This once again matches Saunders' framework: the expansion of the domestic circle involved in nuclear policy decisions diluted Aldermaston's influence.[91] When incorporated into a wider defence bureaucracy, the personal relationships between Aldermaston's key advocates and political decision makers was less consequential.

In judging the validity of claims of nuclear 'uninvention,' the ability of external parties to determine AWRE's requirements was deemed important, but between 1947 and 1993, never satisfactorily resolved. Although hindered by secrecy and attracting the ire of Henry Tizard and the ARD, the HER project was able to cite its priority to acquire its needs. This continued with the thermonuclear programme, with the Treasury frustrated with AWRE's profligacy. When reductions were imposed upon the nuclear programme from the early 1960s onwards, the persistent fear was in "cutting blind."[92] Attempts to apply further scrutiny to the establishment to determine their minimum manpower requirements with the both the Kings Norton Inquiry and the 1988 Industrial Society review proved unproductive. Especially in the late 1960s, AWRE sometimes actively resisted scrutiny from external officials. As in Kampani's study of India, government oversight of nuclear weapons establishments inherently suffers from principal-agent issues such as of bounded rationality and limited domain expertise.[93]

The incorporation of tacit knowledge in 'uninvention' arguments further exacerbated these principal-agent issues. The "special skills" held by weaponeers at Aldermaston were both a fragile commodity that could be lost but also an unknowable factor for those on the outside.[94] Guarded by both official secrecy and often an unofficial reluctance to cooperate with other departments, who were external officials to tell figures such as Cook what were the establishment's needs? This was demonstrated with the long-standing contest over what figure represented the minimum manpower

[90] Committee of Public Accounts, Ninth Report, Session 1981–1982, Ministry of Defence: Improvement to the Polaris Missile System, 17/03/1982, p.13
[91] Saunders, (2019), p.175
[92] Jones, (1)(2017), p.237
[93] Kampani, (2014), p.72-3
[94] TNA, CAB134/2239, Research and Development Policy for AWRE 1962-67, 27/09/1962

requirement of the weapons establishment in the prelude to the Kings Norton Inquiry was. The inability of the Treasury to challenge the often repeated 6000 figure is telling. Nuclear weapons related tacit knowledge was therefore both a shield from scrutiny and a powerful tool in advocating their own institutional interests.

Nonetheless, the principal's will could prevail; if a sufficient consensus was mobilised, governments could proceed to make nuclear defence spending reductions. Macmillan's government and successive governments in the 1970s were willing to make arbitrary reductions to staffing at Aldermaston, often despite warnings of the possibility of skill loss. In the case of reductions after the Kings Norton Inquiry, this resulted in the crisis of 1979 that required both physical and social repair to keep AWRE functional. The inability to conduct multiple weapons programmes at the same time at Aldermaston limited the Thatcher government's nuclear weapons development options and ensured that WE-177 replacement was delayed beyond the end of the Cold War, resulting in its cancellation. There was therefore a tangible risk to the future of the UK's nuclear capability in overruling what the establishment deemed was necessary.

To lessen principal-agent problems by accurately gauging the needs of the weapons establishment and broadening consensus over the formulation of nuclear weapons policy, the UK government has attempted to create nuclear weapons "epistemic communities" beyond the weapons establishment itself.[95] This has included the creation of ministerial committees and advisory bodies such as the Nuclear Requirement for Defence Committee in the 1960s and the Nuclear Research Advisory Council more recently. The greatest organisational development intended to provide greater control and oversight over AWRE was for it to be placed under the MoD Procurement Executive in 1973, removing it from the ineffectual oversight arrangement under the UKAEA and MinTech. As argued, this had been directly spurred by the Kings Norton Inquiry and its failure to find grounds for staffing reductions. The recent creation of the Defence Nuclear Organisation appears to be an attempt at centralising nuclear relevant expertise within the MoD to better manage the government's relationship with AWE.

While institutional development to increase scrutiny appears to have been one possible outcome of the process based on the inherent problems of knowledge management at the establishment, the alternate response was to provide the establishment with more autonomy. This was the logic behind the foundation of the UKAEA and shift to contractorisation, where it was hoped that by removing the restrictions placed upon the establishment by its inclusion within the civil

[95] Kampani, (2014), p.69, p.73-75

service and injecting more dynamism from the private sector, the nuclear weapons establishment would be both more attractive to employees and more efficient in delivering results. While this may have been the intention, the experience of AWRE under the UKAEA in the 1960s suggests that it did not solve the underlying issue of the need to supply the establishment with a continuous stream of work. Instead, institutional autonomy exacerbated principal-agent problems by allowing for the weapons establishment to promote the idea of the fragility of its institutional knowledge in the absence of rigorous oversight, technical solutions became the means to solve knowledge management problems.

This thesis suggests that between 1947 and 1993 there was an inherent problem of knowledge management at Britain's nuclear weapons establishment that drove it towards heterogeneous engineering. The establishment's understanding of the need to retain skills meant that it developed a sense of the need for a constant flow of work. When projects lessened in the early 1960s, AWRE actively began to advocate for its institutional interests. Their arguments claimed that unless there were new nuclear weapons programmes, AWRE would lose the ability to maintain the arsenal in the future. An argument premised on tacit knowledge posed inherent principal-agent challenges. External parties were unable to scrutinise tacit knowledge-based claims, and these were used to justify the initiation of the Polaris Improvement Project. However, such arguments were not singularly influential. When governments mobilised consensus on nuclear weapons decisions, Aldermaston either benefited or had its objections overruled. When government delegated decisions, AWRE could use its institutional authority to press heterogeneous engineering attempts via 'uninvention' arguments. Successive governments then responded by either providing Aldermaston with greater autonomy to manage their workforce more effectively or implement measures to reduce officials influence over policy and provide greater oversight. Whichever path was chosen, the problem of maintaining skills at the establishment appears to have cyclically reoccurred, with maintaining skills again being used to argue for institutional interests.

Implications and Further Applications

While this thesis has only examined the history of the British nuclear weapons project, its findings are relevant to other states. As detailed in the framework, creating and maintaining nuclear weapons entails a series of knowledge management challenges. Accurately assessing required levels of tacit knowledge to maintain a nuclear arsenal, independent of institutional interests are and were

unresolved issues.[96] As highlighted by this thesis, Kampani's work on India and Hymans and Braut-Hegghammer's studies, providing effective oversight over a nuclear weapons programme poses inherent principal-agent problems.[97] As observed by Sims and Henke in the US and repeatedly in the British case, weapons establishments can further problematise this relationship by using knowledge management arguments from a position of experiential authority.[98] Although the history of the British weapons effort demonstrates that governments could overrule fears of nuclear weapons 'uninvention,' this required policy attention towards expanding "the domestic circle for nuclear policy" to mobilise a consensus for deprioritising the programme.[99] When weapons decisions were delegated, the information asymmetries enjoyed by the establishment's nuclear advocates allowed for greater assertion of their "bureaucratic independence" in influencing policy decisions.[100] As highlighted by Schmidt, Polanyi's original conception of tacit knowledge was intended to subvert government control of science and under these conditions, knowledge management arguments were often used successfully in this role.[101] Although used to promote institutional interests, warnings over nuclear 'uninvention' cannot be routinely ignored if the intention is to keep a nuclear arsenal functional either. When successive administrations imposed arbitrary reductions in the 1970s, AWRE faced serious challenges to ongoing production.

As knowledge management and organisational requirements needed to operate a nuclear weapons programme are high, all nuclear weapons states or proliferants would be expected to confront the dilemmas documented in the British experience eventually. This is already evident by the US troubles with FOGBANK and the problems with scientific capture within the Iraqi programme explored by Hymans and Braut-Hegghammer or Kampani with India.[102] While this thesis does not propose a solution, it does suggest that the desire to stave off the potential for nuclear weapons 'uninvention' is a possible driver for vertical nuclear proliferation. While state nuclear arsenals exist, a high level of nuclear weapons reliability is deemed important, and unless the capability to design and replicate advanced nuclear weapons is completely and irreversibly 'black boxed' (which seems unlikely), there will be pressure for further nuclear weapons developments to allow for the transmission of knowledge regardless of other strategic considerations. Providing oversight to determine what level of skills are necessary for a nuclear establishment to function proved extremely challenging in the British case due to a combination of secrecy and the uncommunicable

[96] Carrigan, (2007), p.275 & MacKenzie, (1999), p.186
[97] Kampani, (2014), Hymans, (2012) & Braut-Hegghammer, (2016)
[98] Sims and Henke, (2012), p.324
[99] Saunders, (2019), p.170
[100] Kampani, (2014), p.72 & Saunders, (2019), p.175
[101] Schmidt, (2012), p.194
[102] See Chapter 1.

technical authority conveyed by arguments based on tacit knowledge. Governments further worsened oversight when they delegated nuclear decisions to a limited nuclear defence bureaucracy, especially when civilian bodies meant to provide external scrutiny (such as the NRDC or MinTech) were left unempowered. This situation could be enhanced by strong "internal opacity" as Kampani observed with India, in "personalist regimes" such as Iraq, where according to Braut-Hegghammer, states undergo a degree of "coup-proof[ing]" which "can further weaken their ability to monitor and intervene in the management of nuclear weapons programs" or under governments, such as Wilson's, where they are unwilling to expend political capital on mobilising towards an affirmative policy decision.[103]

As demonstrated in the British case, knowledge management issues are exacerbated by the uneven flow of nuclear weapons work due to having a limited arsenal. This is especially apparent in the UK as it is distinct from Russia and the United States in that it maintains a singular nuclear system delivered "at the lowest practicable cost," delivered by a single nuclear establishment. [104] As a result, Britain has more akin with other nuclear states with smaller arsenals and potential proliferation aspirants in the scale of its nuclear ambitions. The struggle of balancing economic considerations, scientific capacity and balancing nuclear defence spending with conventional programmes is also likely an ongoing challenge to India, China, France, Israel, North Korea and Pakistan. As noted in the framework, while knowledge management demands may be avoided by reliance on "relatively crude nuclear weapons," none of the listed states have adopted this approach.[105] All nuclear weapons states appear to incorporate at least tritium 'boosting' into their nuclear arsenals.[106] It would therefore be expected to find institutional pressure to continue vertical proliferation programmes to further the transmission of perishable tacit knowledge in the states listed above. How these countries balance knowledge management and institutional interests is an area for future research but as noted, currently limited by the availability of sources.

States with large nuclear arsenals such as Russia and the United States would be less affected by this process. Rotating programmes of refurbishments across different systems could ensure a steady flow of employment. Nevertheless, similar arguments are cited in the United States: a 2015 workshop conducted by the American Association for the Advancement of Science and Union

[103] Braut-Hegghammer, (2016), p.6, Saunders, (2019), p.165 & Kampani, (2014), p.78
[104] TNA, CAB148/369, UK Nuclear Warhead Capability and Prospects for Cooperation with France and the US, 24/01/1994
[105] MacKenzie, (1999), p.192
[106] See country profiles on Korda and Kristensen, (2019)

of Concerned Scientists with US nuclear weapons scientists, engineers and defence officials found that:

"There was some discussion of what was needed to maintain such expertise at the U.S. labs, with some arguing that the labs would end up with second-rate people if there was not challenging work for designers to do—and that "make-work" would not be adequate. Some asserted that the downside of refurbishing existing nuclear weapons rather than designing new ones was that the labs would lose the best people."[107]

Given this "challenging" work was designing a new warhead, the similarity between this suggestion and arguments used to advance Chevaline in 1960s Britain cannot be ignored. This further suggests that efforts at 'black boxing' nuclear weapons design in the US or UK have as of yet not eliminated the perceived need for retaining expertise through ongoing new nuclear weapons programmes. In addition, when announcing Britain's new nuclear warhead development programme in 2020, the SofS for Defence highlighted the linkage between "build[ing] the skilled teams and put in place the facilities and capabilities needed to deliver the replacement warhead; whilst also sustaining the current warhead until it is withdrawn from service."[108]

The apparent need for continuing vertical proliferation to sustain tacit knowledge transmission suggests two interlinked possible implications for disarmament policy, although both likely lessened by 'black boxing' and designs incorporating inherent reliability and minimal maintenance features. The first is that successive generations of nuclear weapons will still be periodically required to both physically repair warheads and to renew tacit knowledge. As Ritchie notes, the common trend of intergenerational price increases for defence systems can be observed for nuclear weapons; for Britain, capital spending at AWE has been a significant source of these rises.[109] This means at the point of needing to renew a nuclear arsenal, the question of whether "remaining in the nuclear weapons business" is worth the price will have to be revisited and will likely be more difficult each time.[110] Neither intergenerational price increases or nuclear tacit knowledge requirements are unique to Britain, so this pressure is likely to be universal to nuclear armed states.[111] The second interlinked implication is that any disruption at a weapons establishment is likely self-reinforcing and has long term consequences. Without government prioritisation, AWRE declined in the 1970s; the loss of skilled staff due to low pay aggravated safety

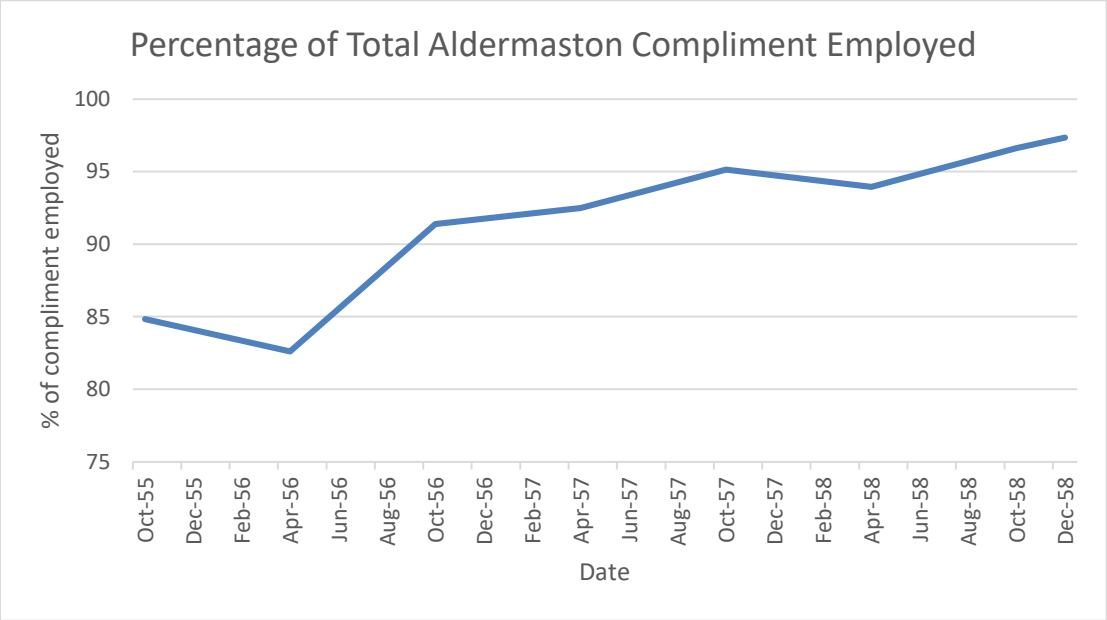
[107] Union of Concerned Scientists and American Association for the Advancement, (2015), p.7
[108] HM Government, 2020
[109] Ritchie, (2012), p.160
[110] Ibid., p.163
[111] Hove and Lillekvelland, (2015)

issues. This limited the Thatcher governments nuclear ambitions and impacted the Trident programme into the 1990s. As seen throughout this thesis, recruiting and retaining staff, building and rebuilding physical infrastructure and organising the effort required considerable government attention and investment to implement. Therefore, even if knowledge is no longer so individually based, the collective and local character of the work conducted by weapons establishments still leaves them vulnerable to interruption and degradation. Overcoming the challenges imposed by a "hiatus" would therefore likely require the considerable investment that MacKenzie and Spinardi foresaw for nuclear weapons "reinvention" in 1995.[112] If international and domestic factors exert pressures towards disarmament, managing and justifying such national efforts may prove increasingly challenging given the investments required.

[112] MacKenzie and Spinardi, (1995), p.47

Annex 1

Percentage of Total Aldermaston Complement Employed, 1955-1958



Data Source: TNA ES1/1503, “Complement and Strength of Staff at Aldermaston,” 24/12/1958

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CAB128/27

CAB129 - Cabinet: Memoranda

CAB129/56

CAB129/69

CAB129/86

CAB130 - Cabinet: Miscellaneous Committees: Minutes and Papers

CAB130/101

CAB130/16

CAB131 - Cabinet: Defence Committee: Minutes and Papers

CAB131/23

CAB131/27

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